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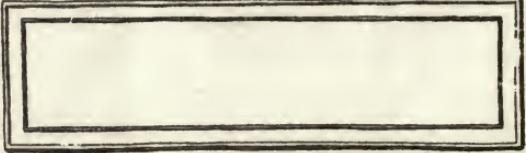
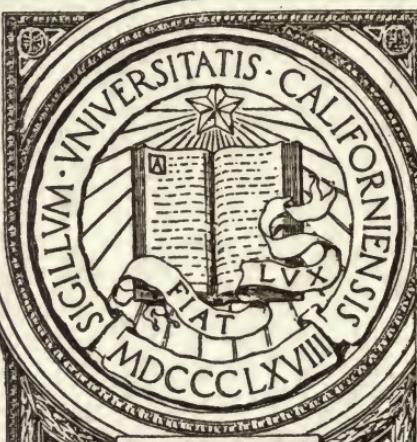


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NEW THEORY
OF
TERRESTRIAL MAGNETISM.

(READ BEFORE THE NEW-YORK LYCEUM OF NATURAL HISTORY.)

BY SAMUEL L. METCALF, M. D.,

MEMBER OF THE NEW-YORK LYCEUM OF NATURAL HISTORY.

"Omnis artes, quae ad humanitatem pertinent, habent quoddam commune
vinculum, et quasi cognatione quadam inter se continenter."—CICERO.

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P R E F A C E.

No subject, perhaps, has more engrossed the attention of philosophers, for the last two centuries, than that of magnetic polarity. The cause of this interesting phenomenon has, hitherto, evaded their researches and baffled their ingenuity, until many have abandoned the problem in despair, as an inscrutable mystery. Such despondency is inconsistent with the progress of knowledge, and the spirit of genuine philosophy. Had such men as Columbus, Watt, and Fulton, been discouraged by the narrow and sceptical views of those who could not comprehend their reasoning, the advancement of civilization would probably have been retarded for centuries. Had Galileo, Newton, and other exalted spirits, been deterred from their inquiries, by the scoffs of their bigoted contemporaries, we might still have been ignorant of the laws of gravitation, and frightened, like savages, by the appear-

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ance of every new comet, that approached the orbit of our planet.

We cannot assign limits to the scope of the human mind in discovering the causes and relations of things, when fully exerting its native freedom, unfettered by the trammels of prejudice and the routine of authority. It is by many persons considered presumptuous and disrespectful to question the opinions of men, whose discoveries in science have placed them high on the rolls of fame above their contemporaries. Such a spirit is detrimental to the progress of true knowledge. There should be no standards of infallibility in science, but demonstrated truths.

We have been created with an unquenchable desire to penetrate the veil with which Nature conceals her mysterious operations:—nor was it intended that this desire should be disappointed. With patient thought and persevering application, it is impossible to limit the results which may flow from the discovery of a single truth:—for it is the essential nature of truth to impart a divine illumination to the soul, by which it is strengthened and prepared for still higher attainments. A brilliant train of new ideas spring up from every quarter, and the labor of years is accomplished in as many

P R E F A C E.

months. Like the sun, it sheds light and beauty over every object which it touches, irradiating the path of future research.

The most important acquisition ever made to the stock of human knowledge, was the discovery of the directive power of the magnetic needle. During the most enlightened periods of Greece and Rome, commerce was restricted to a coasting navigation. With no other guide than the stars, it was impossible to explore distant regions, across wide and trackless seas ; but since the discovery that a piece of metal horizontally balanced, is constantly directed to certain points in the polar regions, the nations of the earth have become one great family—civilization and Christianity have been carried to the most distant islands of the ocean ; and man has extended his dominion over the whole habitable globe.

A NEW THEORY
OF
TERRESTRIAL MAGNETISM.

P A R T I.

1. THE principal difficulties which have attended all inquiries in relation to Magnetism, have arisen from our vague and imperfect knowledge of the *cause of attractions* generally. Simple as it really is, we have never had a satisfactory solution of the cause of capillary and cohesive attraction. The most brilliant and original discovery of Sir Humphrey Davy, was the supposed cause of chemical attraction, which he referred to the agency of opposite electricities in different elements. It must be acknowledged at the same time, that his definition of electricity is vague and obscure, if not entirely erroneous. He says, that "electricity appears to result from the general powers or agencies of matter." He also denies the materiality of caloric.

2. It will be our first object in this Essay, to trace some of the most striking analogies of caloric and electricity—to show that they are radically the same subtle, imponderable, and all-pervading element; and that its unequal distribution throughout Nature, is the cause of all the various powers and attractions of ponderable matter with which we are acquainted.

3. A complete history of caloric would embrace an account of all the changes and transmutations perpetually going on throughout matter. It is the grand instrument of the Almighty by which He executes the laws of nature. It is caloric that thunders in the Heavens, as the voice of Omnipotence ; which raises mountains from the ocean, and piles them like turrets in the sky. It expands in the deeps below, and the earth trembles ; rocks are melted, and pyramids of flame ascend above the clouds.

4. But in all its operations, its general agency is conservative. It is the source of life and motion throughout creation. Its entire absence would mark the reign of everlasting silence and death.—It preserves the ocean in a fluid state, and imperceptibly raises its waters into the atmosphere, to be distributed over the dry land. The atmosphere itself would be a motionless mass of inert and chaotic matter, were it not for *caloric*.

5. It seems to be a general law of this subtle element, that *it repels its own particles, and is attracted, though unequally, by all other matter, with an increased ratio as the squares of the distance diminish.*

6. From which it follows, that when caloric is withdrawn from a body, that body has a stronger affinity for caloric, than one which is filled with it ; and that two bodies charged with caloric, one plus and the other minus, will attract each other with a force proportioned to the different quantities of caloric which they contain, and to the rapidity of its conduction from one to the other.

7. An experiment, which I inadvertently made when a child, strikingly illustrates this principle. On the morning of "cold Friday," as it was called throughout the Western

Country, I applied my tongue to a plate of cold iron, while the mercury was about 15° below zero, when it adhered with such force that the skin was removed on separating it. Captain Scoresby relates, that frequently such was the intensity of cold in the Arctic seas, that the hands of the sailors adhered fast to whatever metals they touched.

8. In all such cases the temperature of the living body is from 115 to 140 degrees higher than that of the metals:—in other words, the living body is charged plus, while they are minus; and the attraction continues until the equilibrium is restored, when it ceases.

9. The same attraction takes place when the hand is applied to metals heated greatly above the temperature of the living body; and for the same reason, one of the two bodies being charged plus and the other minus.

10. When the temperature of metals is greatly reduced, they become brittle, so that a slight blow will fracture them: the same effect is produced on iron by hammering, which presses out, and expels from it that portion of caloric, which is necessary to its cohesion and malleability. Hence it follows, that a certain amount of caloric between the particles of matter is requisite to maintain their cohesion; but when the amount of caloric is increased beyond a certain extent, it separates the particles, and thus diminishes, or overcomes, the power of cohesion.

11. A great variety of facts may be adduced to show, that *capillary attraction* is owing to the operation of the same law. For example; if a piece of sugar be put into a glass of water, a portion of the caloric of fluidity leaves the water, enters among the particles of sugar, and diffuses itself equally

throughout the whole. During this absorption of caloric by the sugar, the temperature of the resulting mixture is somewhat reduced, proving that, in relation to the water, the sugar is minus or negative, and the water is plus or positive.

12. If the piece of sugar be cut into a cylindrical form, of one or two inches diameter and five or six inches long, and one end of it only be inserted into a glass of water, the caloric of the positive fluid being *strongly attracted* by the negative sugar, pervades it rapidly throughout, until the equilibrium is restored, when the entire mass is dissolved.

13. M. Lehot found by experiment, that under the same pressure, water rises higher in vertical capillary tubes as its temperature is elevated. (*Bibl. Univers. Mars.* 1820, p. 225.)

14. The phenomena of a burning candle illustrate the agency of caloric in producing capillary attraction in a very striking manner. The wick is ignited, the tallow rendered fluid, and attracted by caloric so as to furnish a continual supply of combustible matter to the wick, which is decomposed and expanded into flame or light. The force and rapidity of capillary attraction, all other things being equal, are in proportion to the amount of heat given out in the wick.

15. Capillary and cohesive attractions are only modified effects of the same cause. It is the attraction of caloric for the particles of water, that holds them together; that gives its drops their globular form; as it is the attraction of caloric for porous solids, and capillary tubes, that raises the water above its ordinary level.

16. The same reasoning applies to every solution of crystallized salts, ice, &c. and to every case of capillary attraction. Though this principle has never been fully understood, it has

long been applied for the production of artificial cold. The solution of muriate of ammonia in water greatly reduces its temperature; and if five parts of muriate of ammonia and five of nitre be *dissolved together* in sixteen parts of water, the temperature of the mixture will be lowered forty degrees,—the negative salts attracting and absorbing the caloric of the positive water.

17. Another proof that salts, &c., are dissolved by caloric is, that they again become crystals on the abstraction of caloric, or as the solution cools down. Moreover, the solvent power of water is increased as its temperature is increased. Some salts are soluble in alcohol, that are insoluble in water; and it is obvious, that the specific heat of alcohol exceeds that of water, from the following experiment. We put half an ounce of ice by weight, into an ounce of alcohol; and the same quantity in an ounce of water, at the same temperature, when the ice in the alcohol dissolved in twenty-four minutes; while that in the water dissolved in twenty-eight minutes. In ten minutes after the ice was put in each vessel, the temperature fell to thirty-two degrees in the alcohol, and to forty-one degrees in the water, showing that the ice abstracted caloric from the alcohol faster than from the water.

Sulph. Sol.
Chl-barium
& V-Y-
tart-potash

18. The greater quantity of latent caloric in alcohol than in water, explains why it evaporates at a lower temperature than water—and why it is not congealed by cold. The greater quantity of caloric between its particles, prevents their cohering into a solid state, and carries them off in the form of vapor, when in open vessels. For the same reason, gaseous bodies cannot be congealed, except by great pressure, which evolves an enormous quantity of heat. All bodies exist in a

solid, fluid, or gaseous state, according as they contain more or less caloric.

19. Philosophers have generally attributed the coldness produced by solution, to a change of volume; but this is mistaking the effect for the cause. A portion of the sensible caloric of fluidity leaves the water, enters among the particles of the solid crystal, converts it into a liquid, and thus becomes latent, which causes the coldness.

20. Solution is merely the diffusion of caloric among the particles of bodies, in search of an equilibrium. The cause of all the motions of caloric is its repulsion of its own particles, and attraction for other matter.

21. Philosophers have never explained to us why oxidation or combustion, goes on more rapidly at a high than at a low temperature. They say, that caloric expands the combustible materials, produces a vacuum, and thus affords free access to the atmospheric oxygen; but this is not satisfactory. It is extremely probable, that the attraction of caloric for oxygen is the cause of its rapid combination with the combustible materials.

22. The attraction of caloric for ponderable matter is not limited to small spaces. In the great laboratory of nature, it acts on a large scale, where it is the cause of evaporation. Its attraction for water causes it to enter into, and expand its particles, by which it is carried into the atmosphere, in the form of vapor—which is thus charged positively with caloric; while the attraction of the same caloric for bodies charged negatively, draws the vapor towards them. Thus mountains which are colder than the atmosphere at the same elevations, and therefore negative, attract distant masses of vapor which are positive, abstract their caloric, and so cause them to descend

in showers of rain, snow, and hail. It was observed long ago by Dr. Franklin, that masses of vapor in different states of electricity, attracted each other far beyond what he called the striking distance.

23. It has probably been remarked by every person of observation, that light masses of vapor from the ocean, on approaching a mass of colder vapor from the northern points of the compass, approximate each other with accelerated velocity, when the colder current of vapor attracts caloric from the warmer ; and it is condensed into a hazy mist or cloud.

24. This is the rationale of all aerial condensations. When a cloud is once formed, having parted with a portion of its caloric, *it is minus* in relation to all uncondensed or transparent vapor, which is plus. So that it becomes a centre of attraction, drawing to it successive masses of vapor, and abstracting their caloric, by which a perpetual condensation or nimbification is kept up, until an equilibrium is restored.*

25. So decided is the attraction of caloric for ponderable matter, and its repulsion of its own particles, that it passes with greatest facility through the densest bodies, which are therefore called conductors—but with difficulty through those which are light, such as gases, furs, silks, woolens, resins, &c., whose pores are filled with caloric.

* After finishing this essay, we witnessed on Sunday evening, June 2, 1833, the most beautiful display of aerial condensations, that we remember ever to have seen. The wind was brisk from the south, and brought from the ocean successive masses of semi-transparent vapor of a red brassy hue, which allowed the rays of the setting sun to pass partially through them, until as they advanced over the city, vivid streaks of lightning darted from them, when *they were suddenly condensed into black clouds*, which entirely intercepted the solar rays, and were attended by rapid precipitations of rain. The showers intermitted and increased several times in the course of half an hour, between the successive flashes of lightning—and during the intermissions, the atmospheric vapor assumed the same brassy color as at first. It will be seen presently, that these remarkable condensations, resulted simply from the giving out in the form of lightning, that portion of caloric which is necessary to hold water in a state of vapor.

26. In tracing the relations of caloric and electricity, it becomes necessary to examine the source from which they are derived, as well as the effects which they produce on common matter. What then is the agent by which water is converted into vapor and raised into the atmosphere? Is it caloric or electricity? Almost all philosophers agree in the answer to this question.

27. It would seem obvious to the most superficial observer, that caloric is the cause of evaporation, inasmuch as the greatest amount of evaporation takes place in regions which receive most of the sun's heat. We may form some idea of the vast amount of caloric contained in atmospheric vapor, when we reflect, that a pound of vapor will raise the temperature of a pound of water nearly 1000 degrees*—that its bulk is increased about 1800 times in passing from a state of water to that of vapor, and that all the rivers of the earth are supplied by its precipitation.

28. What then becomes of all the caloric which must be given out during the condensation of this vapor? We know that thunder and lightning are most abundant in the tropical regions, and during hot, sultry weather in the middle latitudes. Hence we infer, *that the caloric of vapor, when greatly accumulated, is given out rapidly, in the form of electricity, on approaching a colder mass of vapor, which is negatively charged with caloric.*

29. Does it not involve a striking contradiction to say, that vapor is raised into the atmosphere by caloric, and that it is condensed by the evolution of another distinct fluid, called electricity? If so, whence originated the electricity? Are we

* Dr. Hare says, that there is twice the quantity of caloric "given out during a snow storm, that would be given out by an equal quantity of red hot powdered glass."

to suppose with Dr. Thomson, "that when two currents of dry air are moving different ways, the friction of the two surfaces may evolve electricity?" Absurd as this hypothesis may appear, it forcibly illustrates the difficulty of accounting for its origin and existence, when considered as a distinct elementary fluid from caloric.

30. We are not authorized to predicate a primary distinction, until fully acquainted with all the different states and affections of caloric, under different circumstances—for example, in its combinations with different substances, in a solid, fluid, gaseous, or imponderable state—as with the matter of light—its diffusion, concentration, compression, &c.

31. Moreover, we are not philosophically warranted in assigning more causes than are sufficient to explain the phenomena. Now the expansion of fluids by caloric explains satisfactorily the process of evaporation ;—and the passage of the same caloric *out* of the vapor is sufficient to account for its condensation : whether it pass out slowly and insensibly, or with rapid and explosive violence.

32. We know that condensation and precipitation of vapor, often take place, when two currents of vapor of different temperatures unite, without any visible display of electricity. We also know that caloric is given out during all aerial condensations. It is a matter of common observation, that the weather is more hot and sultry in summer during the formation of clouds, than when the air is clear ; and that in winter, it becomes warmer during a fall of rain or snow, unless accompanied by a northern wind.

33. There is not a greater apparent difference between any of the forms of caloric and electricity, than between the elec-

tricity in the atmosphere, and in an exhausted receiver. The explosion of gun-powder, resembles an electric explosion much more nearly, than it does the combustion of ordinary fuel. We often see the heavens filled with sheets of flame, produced by the evolution of caloric from atmospheric vapor.

34. The spark from steel resembles the electric spark, except that it will not pass through conductors : perhaps, because the ignited matter with which it is combined is less subtle.

35. In subtlety, the electric and galvanic sparks are equaled only by the solar rays. What can be more different than caloric in its free, and in its latent state ? When we shall understand more thoroughly *how* caloric assumes so many different states and appearances, we may discover how it exhibits electrical phenomena.

36. Before caloric combines with, and expands water into atmospheric vapor, it is universally acknowledged to be sensible heat ; after it enters into the water and converts it into transparent invisible vapor, its state is changed ; and, when greatly accumulated in this state, it exhibits *electrical phenomena*. To say, however, that its elementary nature is changed, would be as unphilosophical, as to contend, that the latent caloric of water is specifically different in its nature from the same caloric, when set at liberty by pouring water on calcined lime ; or that it is distinct from the caloric which moves a steam engine by its expansion ; or that the galvanic fluid is distinct from the electricity of a Leyden jar, because it moves with less velocity. But it is universally acknowledged that galvanism and electricity are essentially the same fluid ; and we shall show hereafter, that galvanism is developed by the combustion of metals in acids, alkalies, or atmospheric air.

37. Had philosophers attended more carefully to the great changes which take place in the states of caloric, produced by its various *modes* of combination with other matter in different forms, they would probably have been led to discover more clearly, if not the identity of caloric and electricity, *at least that they are inseparable*, and *that without caloric there could be no electricity*.

38. We know that a Leyden battery may be filled with the electric fluid drawn from a living man; and that a living man may be charged with the electric fluid until it runs over, producing palpable currents.*

39. Many experiments have been made by M. Pouillet and M. Becquerel in France, since the publication of Sir Humphrey Davy's Chemical Philosophy, to prove that chemical affinities are owing to electrical attractions.

40. Becquerel obtained the following results:—"When an acid combines with an alkali, a current in one uniform direction is established. The acid furnishes the positive, and the alkali the negative electricity. When nitro-muriatic acid acts upon gold, the acid is positive and the gold negative. In general, an acid, during its action on a metal, is either negative or positive, according to its concentration or dilution."

41. "A mixture of a concentrated solution of an acid with a dilute solution of the same acid, produces electrical effects; the concentrated acid liberates the positive, and the dilute acid the negative electricities."

42. "If into a filtered solution of the nitrate of iron, two leaves of platinum foil be immersed, these leaves at the same time communicating with the two ends of a multiplying wire,

* It is this fluid united with organic matter which produces animal heat.

if one of the leaves be suffered to remain in the solution, and the other be withdrawn, and again immersed, a current of electricity is produced, and the leaf which is re-immersed will always liberate the positive electricity."

43. In all the above experiments, what is the electricity developed, but the liberation of the latent caloric of the different substances employed, as their states are changed?

44. "We have been the more particular," says Dr. Green, to whom we are indebted for the account of these experiments, "because they appear to us to throw considerable light on the mutual relations which subsist between chemical and electrical attractions—relations which seem to govern the union and combination of all material substances."

45. M. Pouillet found by experiment, that electricity was evolved by the combustion of charcoal; and that whenever two gaseous bodies unite with each other, or a gaseous with a solid body, one of them gives out positive, and the other negative electricity. It is susceptible of demonstration, that all elements in a gaseous state contain caloric in proportion to their specific gravity. The most dense contain it minus;—while the lightest contain it plus. (*Ann. de Chem. et Phys.* XXXV. 401., and *Thomson on Caloric and Electricity*, p. 497.) In reality, it is difficult to imagine any other cause of specific gravity than caloric. M. Pouillet also proved, that during the combustion of hydrogen, ether, alcohol, wax, fat, and many vegetable substances, a zone of air surrounding the flame was electrified plus, while the interior of the flame was electrified minus. His inference was, that during the combustion, the atmospheric oxygen gives out positive electricity,

while the carbon and hydrogen of the combustible bodies give out negative electricity.

46. If M. Pouillet's experiments are to be relied on, electricity is evolved during every combustion which takes place; also during the respiration of all plants. So much for the agency of caloric in producing chemical affinities. We hope to resume this interesting subject on another occasion, when we shall have more leisure to pursue it.

47. One of the most decisive proofs that caloric and electricity are convertible into each other is, that during all condensations of aerial vapor, whether into rain or snow, during winter or summer, caloric is given out in very large quantities. It is notorious among the vulgar, that the air is rendered hot and sultry, during summer, before showers, which is owing to the heat given out by the transparent vapor as it condenses into clouds, as before stated; also, that the temperature is greatly moderated by a fall of rain or snow during winter. In the above examples we perceive, that the same fluid, which, when greatly accumulated in the atmosphere, and suddenly given out, causes lightning and thunder; under ordinary circumstances of condensation, is given out silently, producing no other sensible effect, than to raise the temperature.

48. Dr. Franklin was greatly puzzled to account for the origin of atmospheric electricity. At one time he supposed that it was produced in the ocean, by the friction of salt and water; but afterwards finding this hypothesis unsatisfactory, because he ascertained that clouds were negatively electrified, and that all bodies were more or less filled with electricity, he imagined that the electric stroke passed from the earth to the

clouds, and not from the clouds to the earth:—an hypothesis still less tenable than his former one.

49. Mr. Daniell closes his late excellent work on Meteorology, by stating, “that the interesting subject of atmospheric electricity has been almost totally neglected;” and “that at present, he had nothing to offer on this most important branch of physical science.”

50. Dr. Thomson says, “that the formation of vapor seems to be connected with electricity, though in what way the vesicular form is induced by electricity we have no conception.” It is indeed very difficult, if not impossible, to conceive *how and whence* the electricity originated, if it be not caloric. He adds further, “the formation of rain is still involved in impenetrable obscurity.”

51. With due deference to the opinion of Dr. Thomson, the rationale appears very simple, if we admit that caloric and electricity are convertible into each other. Water is expanded by heat into transparent vapor—raised into the atmosphere, where it remains suspended, until it approaches the vicinity of a mountain, or a mass of vapor, at a lower temperature, when the attraction of caloric for those bodies which contain less of it, causes it to leave the transparent vapor, and it coalesces into mist, clouds, rain, snow, or hail. If the difference of temperature be great between the masses of meeting vapor, the equilibrium is restored suddenly by a violent explosion, in the form of the electric spark or lightning. During winter, the difference of temperature between different masses of vapor is usually small in the middle latitudes, so that the equilibrium is restored gradually and without explosion. During spring, and especially in April, when masses of warm and cold vapor

frequently meet, light showers are precipitated, by the sudden passage of caloric from one to the other—still without much thunder and lightning.

52. But in summer when the atmosphere is saturated with transparent aqueous vapor, *which is full of caloric*, its approach to a mountain or a mass of vapor charged minus, is attended with rapid and sudden transitions of caloric from the plus to the minus body, causing terrific explosions of thunder and lightning.

53. A large body of vapor from the tropics resembles an immense Leyden jar, charged with caloric or lightning. The globe itself is but the grand laboratory of nature, which the art of man has imitated on a Lilliputian scale.

"Neque aliud est natura quam ars quædam magna."

LEIBNITZ.

54. Dr. Arnott has given substantially the following explanation of rain, in the *first volume* of his work on *Nat. Phil.* p. 348. The production of rain and snow, he attributes to the elevation of watery vapor into the higher regions of the atmosphere, where, from the greater dilatation of the atmosphere, it becomes colder, and thus condenses the atmospheric vapor. He takes no account of the *diminished quantity of caloric in clouds already formed*, and in mountains, high plains, &c., which abstract caloric from invisible vapor, and cause it to descend in rain.

55. It is notorious that when the wind blows steadily in one direction, for some time, over a level country, very little rain falls. In the great desert of Sahara, there is scarcely any rain, because the vapor transported over it by the west wind is still further rarified by the heat of the scorching sand,

where there are no mountains to condense it. For a similar reason, we often have long droughts in the level parts of the United States during summer. Owing to the great heat of the atmosphere, the vapor brought from the Atlantic ocean by southern and eastern breezes, is not condensed, but still further expanded, until it meets with a current from the northern points of the compass—a descent of cold air from the higher regions*—or with mountains and highlands of a lower temperature, when thunder gusts follow.

56. After a long drought, the first precipitations take place over moist ground, river courses, &c.—which are colder or negative, and therefore attract the electric fluid from the positive atmospheric vapor. Hence it frequently occurs, that such situations receive two or three showers, before the rain becomes general.

57. When the aerial vapor is condensed into a cloud, by giving out a portion of its caloric, it becomes negative in relation to the surrounding vapor, and attracts caloric from it; which also becomes negative, and acts on the neighboring vapor in the same way, until it is successively condensed for several hundred miles, and the rain becomes general. When the equilibrium is restored, the storm ceases, and the sky becomes serene.

58. Our equinoctial storms are produced by the meeting of extensive masses of vapor, from opposite quarters, of different

* Dr. Thomson has asserted that air cannot descend without giving out its caloric as it falls, which he thinks would prevent it from cooling the temperature of the lower atmosphere. He seems not to have been aware, that the upper air may be more condensed by cold than the lower air by pressure, in which case its descent would be attended by a reduction of temperature, in proportion to the mass which descends from above. The sea and the air over it are less heated, because the water on its surface rises in the form of vapor, carrying off a great portion of its caloric.

temperatures. The vast amount of condensation, caused by the meeting of opposite currents, while the sun is passing the line, occasions extensive vacuums—a violent rush of elastic vapor from different quarters is the consequence, constituting whirlwinds, hurricanes, and tornadoes.

59. In the United States, the difference of temperature between northern and southern winds, is much greater than in Europe, which has a maritime climate, and on the ocean generally, where the temperature is more uniform; for this reason, we have more intense lightning than in Europe and on the ocean, and not as M. Volney supposes, "because of the greater dryness of our atmosphere." The most violent thunder storms on the American continent occur in July and August, when the air in the middle latitudes is greatly rarefied, so as to favor a descent of the cold upper current from the equator.

60. Dr Franklin believed, that vapor was held in a state of solution by electricity, but it is evident that caloric is the vaporizing agent all over the world. It would seem a waste of time to say more in proof of the identity of caloric and atmospheric electricity. There is no thunder and lightning in the polar regions.

61. Before leaving this interesting subject, it may be proper to take a cursory view of the agency of caloric in producing atmospheric currents generally.

62. There are three great currents of the aerial ocean, by which it is kept in perpetual circulation:—one from the polar regions towards the equator, which is an under current:—another from the equator to the poles; which is an upper current:—and a third, called the equatorial current, or trade wind; which

blows from east to west, around the globe, for about thirty degrees on each side of the equator.*

63. There is another general wind which blows from west to east, in the middle and higher latitudes; in the northern hemisphere about two thirds of the year: while in the southern hemisphere, it is nearly as uniform as the trade wind, where there is no land.

64. Dr. Hadley, and after him, Dr. Franklin, attributed these currents to the following causes. "The air under the equator and between the tropics, being constantly heated and rarefied by the sun, rises: its place is supplied by air from the higher and polar latitudes, which, coming from parts of the earth, that had less motion, and not suddenly acquiring the quicker motion of the equatorial earth, becomes an east wind blowing westward; the earth moving from west to east and slipping under the air." Mr. Daniell has shown conclusively, that, from the greater density of the polar atmosphere than the equatorial, its height is proportionally less: so that the air rarefied between the tropics, and rising, must flow toward the poles. Before it rose, it had acquired the greatest motion the earth's rotation could give it: It retains some degree of this motion, and descending in higher latitudes, where the earth's

* Our north east winds are often produced by a deflection of the polar current on its passage to the equator, by the more rapid motion of the lower latitudes, in a mode similar to the production of the trade wind.

Variable winds are caused by temporary and local rarefactions—all atmospheric currents, however, are governed by the same general laws.

In the United States, in India, and in southern China, the land becomes greatly heated during summer, while the sun is on this side of the line, which causes a predominance of wind from the ocean, which is then cooler; but when the sun leaves our hemisphere, as in winter, the prevalent wind is from the northern points of the compass—modified, however, in all cases by the revolution of the earth on its axis, by the height and direction of mountains, and by local rarefactions. The semi-annual periodic movements of the atmosphere, caused by the alternate heating and cooling of the land and sea, have been styled monsoons—and by some writers, periodical trade winds.

motion is less, becomes a westerly wind. (*See Franklin's Works, vol. 3. p. 236. and Mr. Daniell on the Atmosphere.*)

65. It was thus Dr. Franklin accounted for the coldness of our north west winds, and of our summer gusts, which are generally from the same quarter. That this is the true mode of accounting for our cold summer gusts, is obvious from the following considerations. The land being greatly heated, rarefies the atmosphere over it, until the superincumbent air sinks down, and mixes with it.

66. At the same time it communicates its tropical motion from west to east; condenses the vapor of the lower atmosphere by absorbing its caloric, and thus produces our western thunder-gusts, which are often attended with hail, and almost always with a great reduction of temperature. In this way clouds are sometimes formed suddenly, the whole sky becoming obscured by dense black vapor. It is a remarkable fact, that thunderstorms almost always occur between mid-day and sunset, when the air is most heated and rarefied, so as to favor a descent of the upper current from the equator.

67. The difference between the temperature of the ocean and atmosphere over it being small, there is little or no dew at sea, and very little thunder and lightning. The unceasing motion of its particles preserves a uniform temperature, being only two or three degrees colder during night, than during day :—while on land the difference is often ten times as great.

68. Air considerably rarefied by heat, receives into it a much greater quantity of vapor before it is saturated than cold air, because it affords much more room between its particles for the expanded vapor to pass through it, and because it does not condense the vapor, but allows it to accumulate in larger quantities

before precipitation. Hence, though there be more invisible water in the atmosphere during summer than winter, there is less visible vapor : more rain in summer, but more fog in winter. In this latter state, the atmosphere is a better conductor of caloric than during summer, which thus passes freely from place to place, without being accumulated, and therefore without explosion. This, together with the diminished quantity of caloric in the atmosphere, is the reason there is no thunder and lightning in the polar regions, nor in our own climate during winter. In the production of dew and frost, the earth is first cooled down by radiation, when it attracts caloric from the stratum of transparent atmospheric vapor immediately over it, by which it coalesces into dew or frost, according to the temperature of the surface.

69. When we examine the mode in which galvanic electricity is produced, we discover a still more intimate relation to caloric than in any of its other forms. We shall find that in every case, it is produced by the combustion of metallic plates differently oxidizable, and that the energy of the pile is proportional to the rapidity with which the intervening acid is decomposed. The oxygen of the acid combines with the metal, and electricity is evolved, in the same way that caloric is given out during common combustion.

70. The principal difference is, that in common combustion, a great portion of the caloric evolved, is carried off in the vapor of the combustible materials in the state of flame, &c., while in the combustion or oxidation of metals by the pile, the caloric is not carried off, owing to the less evaporable nature of the metals ; so that it is concentrated and conveyed by the conducting wires to the extremities of the battery. We shall

also find, that the energy of the battery is proportional to the extent of the metallic surfaces, as well as to the decomposibility of the fluid which supplies the oxygen. When the decomposition of the fluid ceases, the pile loses its energy, and the galvanic current is at an end.

71. We are informed by writers on galvanism, that a few large plates disengage more of the galvanic fluid than a great number of small plates; but that the *intensity* of its action is in proportion to the *number* of plates. They have not given any reason for this difference, which is probably owing to the fact, that the oxidation of large plates, resembles more nearly the process of ordinary combustion, and the calorific or electric currents are combined with a larger proportion of metallic matter—and hence cannot be conducted off by the connecting wires with the same velocity that it is when in a more subtle state. Caloric, electricity, and galvanism, have hitherto constituted a separate and distinct triad of imponderables, perfectly incomprehensible; all the phenomena of which are quite intelligible, if we refer them to the agency of one grand, primary, universal element. Will any philosopher contend, that during the oxidation of metals by a galvanic pile, there are two distinct fluids disengaged, caloric and electricity? or that during the evaporation of water, two distinct imponderable fluids become latent in its vapor? The idea is absurd.

72. The earth may be considered as a huge galvanic pile, and the various combinations and decompositions which mark all its chemical changes, are effected by the agency of caloric in some of its forms.

73. Thus we perceive, that the galvanic fluid is produced in

the same way that caloric is produced, viz., by combustion, or by the union of oxygen with combustibles. M. Pouillet found, as we before observed, that whenever two bodies united by combustion, the supporter gave out positive, and the combustible, negative electricity.

74. We know, that during every combination of oxygen with combustible matter, caloric is given out. There can be no doubt, that all earthquakes, volcanoes, and thermal waters, owe their existence to the *caloric given out* in the lower parts of the earth, in a mode similar to its evolution from a galvanic pile. *It is certainly given out during all oxidations of the earths and metals*—and we know that oxidation is perpetually going on throughout all matter, as far as we are acquainted with it. In treating of atmospheric electricity, we endeavored to show; that it resulted from the accumulation of solar heat in aqueous vapor, and from its rapid passage *out of* this vapor into bodies charged negatively with caloric—from which it follows, that the *sun* is the great fountain of atmospheric electricity. We have seen, that caloric is universally diffused throughout terrestrial matter in a latent state. It can be disengaged from all bodies by pressure, friction, and by chemical decomposition:—electricity is produced in the same way.

75. Caloric in its latent state, does not differ more from its active state, than does sulphuric acid in its separate state, from that of its combination with soda or magnesia. Nor does it differ more from electricity, than does electricity from itself, in an exhausted receiver, and under the pressure of the atmosphere.

76. Dr. Franklin denominated the fusion of metals by

electricity, a cold fusion. He adds, "I do not mean fusion by the force of cold, but a fusion without heat, because, it expands and separates their particles instantaneously, without producing combustion." (*See his Works, vol. 3. p. 51.*) But we know, that if an electric or galvanic current is *continued* through the metals, combustion occurs with *sensible heat*—and if retarded or obstructed in its passage, it produces an explosion. If it be asked why the electric spark does not produce the sensation of heat, we answer, because of its velocity, and the subtlety of the combustible matter with which it is combined. The hand may be held in a shower of sparks produced by the friction of steel with emery, without a sensation of heat, for the same reason, unless the sparks be very large.

77. Dr Hare acknowledges himself obliged to believe, "that caloric and electricity are closely combined," by what he calls "the reciprocal attraction of imponderables." (*See his Controversy with Prof. Silliman on the Nature of Caloric developed by his Calorimotor.*)

78. With sentiments of great respect for the acknowledged talents of so distinguished a chemist as Dr. Hare, we have not been able to find the slightest evidence, that any such affinity exists between caloric and electricity, admitting them to be distinct elementary fluids. On the contrary, I found by experiment, that the end of a metallic rod at a white heat is a bad conductor of electricity; which is probably the reason why the boilers of steam-boats are never struck by lightning when heated.

79. Caloric, which is imponderable, has an undoubted attraction for ponderable matter, which is the reason it cannot

be kept in a separate state, unless insulated by non-conductors, and then only for a limited time ; whether in the form of domestic heat, galvanic, or common electric heat, but universally seeks a latent state, by entering into other matter, and thus becoming a constituent portion of it.

80. The attraction of oxygen for combustibles, which is owing to their being in different states of caloric, causes a perpetual combustion throughout nature. Perhaps there is no such thing as total quiescence in matter. Hence bituminous coal is continually changing by oxidation, and passing into a state of anthracite or hard coal. Hence also the accumulation of caloric, given out by combustion in the bosom of the earth, which is restrained for centuries by superincumbent pressure, until its elastic force overcomes all resistance, and raises mountains, or bursts forth into volcanoes.

81. It is this tendency of oxygen to combine with other elements which causes the various decompositions of organic matter. Its combination with the nitrogen of animal matter in a state of decay, supplies the waste occasioned by the consumption of common air in the respiration of animals and plants. A portion of atmospheric oxygen unites with the hydrogen of animal matter, and produces water ; so that every source of putrefaction, is, to a certain extent, a perpetual spring of regeneration and compensation. In the decomposition of vegetable matter, we perceive the same beneficial results. The oxygen of the air unites with the carbon of vegetable matter, making carbonic acid gas, the appropriate food of living vegetation. And so on through all the endless ramifications of nature, we perceive, that death is only a transmuta-

*the waste
of oxygen,
here over this
we from?*

tion of matter, by which it is prepared for entering into new forms of life and beauty.*

82. Decomposition is merely the separation of the elementary particles of matter by caloric, by which they are prepared for entering into new combinations. How beautiful are the *ordinances of nature!* It would be interesting, if this were the proper place, to show how far the *attraction of vitality* resists chemical decomposition.

83. We have seen that caloric is not only the cause of chemical and cohesive attraction, but, that when accumulated, it is the agent by which the molecular attractions of matter are dissolved. In short, that it is the cause of all the changes which take place throughout the globe. If rocks and salts are dissolved in water, it is caloric which effects it. If rocks and hills are carried down by running water into the plains and seas, caloric is the cause of fluidity. The purification of all metals is effected by caloric, which vaporizes and carries off their drossy combinations.

84. We cannot pass over in silence, what we consider a fundamental error on electricity, which has been embraced by many modern writers in France and England. We allude to the doctrine of two distinct electricities—a doctrine which has no foundation in truth—which is contrary to the simplicity that characterizes all the operations of nature—and which will not bear the test of philosophical analysis. It has arisen from the fact, that vitreous substances are electrified positively, while resinous substances are negative.

85. It is stated by different authors, that whenever a body is charged with positive electricity, it tends to produce nega-

* This is what Pythagoras must have intended to inculcate in his Metempsychosis.

tive electricity, in all the bodies in its vicinity. (*Lib. of U. Knowledge, Article Electricity.*) This fact alone is sufficient to refute the doctrine of two distinct fluids. How is it possible to conceive that a body charged with vitreous or positive electricity, can communicate electricity of another species to a body in its vicinity? The difference is only in degree. The communicating body being charged plus, imparts a portion of its electricity to bodies near it, which become minus or negative. Every attempt to improve this simple and beautiful theory of our countryman, Dr. Franklin, has only rendered the subject of electricity more complicated and obscure. A distinction has been inferred from the difference of form and color of electric sparks produced by positive and negative electricity. As well might we say that there are different species of caloric, modifying the numerous colors of flame in ordinary combustion. The color and form of the electric spark depends on its size, and on the nature of the conductor through which it passes.

86. It is stated, that if a plate of glass with a polished surface be rubbed against one which is roughened, the former always acquires the vitreous, and the latter the resinous electricity. (*See Lib. U. K.*) What better proof could be required, that in the above cases there are not two distinct electricities developed; but that in one case it is plus, while in the other it is minus.

87. It is difficult to conceive how Sir Humphrey Davy mistook the attraction between electricity and ponderable matter, for an attraction between two electricities. When the ponderable elements attract each other, he supposed that it was owing to the attraction of positive for negative electricity.

88. Now it is demonstrable, that when two bodies are charged with the same electricity, one plus and the other minus, whether positive or negative, they attract each other—so that it is owing to the attraction of electricity for ponderable matter, and its repulsion of its own particles, that causes bodies which contain different quantities of electricity to combine. Will it be said that the attraction of my hand for frozen mercury is owing to its being filled with positive electricity, and the mercury with a different species of electricity, which is called resinous?—and that it is the attraction of the two electricities for each other which causes the effect? The idea is preposterous. The hand is plus and the mercury is minus—and caloric is attracted from the plus to the minus body. The above mistake has been a perpetual barrier to a clear understanding of electrical attraction.

89. To enumerate all the effects of caloric would be to give a history of universal nature.

90. It is conceded by nearly all those who have investigated the nature of latent caloric, that it is universally diffused throughout matter; that the form and bulk of all bodies are owing to the existence of caloric between their molecules. For example, the specific gravity of all the gases is the inverse measure of their specific caloric. That of hydrogen being least, it contains the largest amount of specific heat. The specific gravity of aqueous vapor, is less than that of atmospheric air, but its specific heat is greater; and so of all the gases: their specific heat is inversely as their specific gravities.

91. It has been rendered extremely probable by the experiments of Du Long and Petit, "that the specific caloric of every body is inversely as its atomic weight."

92. From the above facts and observations, it follows, that one of the principal functions of caloric is to give volume to bodies by keeping their particles asunder;—that in reality all light bodies are composed chiefly of caloric in a latent state. Hence, the reason why gases and all light spongy substances are bad conductors of caloric, which repels its own particles; while the densest bodies, such as gold, platinum, and silver, are good conductors.* It would be interesting to trace the few exceptions to this general law: for example, why melted resins are better conductors than in the solid state, together with a few others.

93. The small specific gravity of wool, furs, silk, sponge, cork, &c., has been attributed by Dr. Thomson to the diffusion of air through their interstices; but we have shown that the bulk of atmospheric air, and of all other bodies, is owing to caloric, which is easily demonstrated by *condensing* them by pressure, when light and heat are copiously given out, and in many cases accompanied by electrical phenomena.

94. The identity of caloric and electricity is strikingly exhibited by their analogous effects on ponderable matter. Electricity, as well as caloric, expands atmospheric air, water, &c. Dr. Franklin filled a small glass tube with water, and sent a charge of electricity through it, by which it was shattered to pieces, thrown all over the room, and the water evaporated. The same effect is still more obvious with oil. Electricity inflames ether, alcohol, and gunpowder, renders wine red-hot, singes the hair of animals, sets houses, trees, &c., on fire.

* That it is the expansive power of caloric which raises water into the atmosphere, and not its affinity for air, is evident from the experiments of Mr. Dalton, who proved that evaporation goes on much more rapidly in an exhausted receiver than under common atmospheric pressure.

95. The calorific effect of lightning is so intense, that, when it passes down a metallic chain, instead of a rod, it often fuses the chain so as to part it, doubtless owing to the retardation of the electric fluid, by the air between the links, which is a bad conductor. The damage which is usually produced on houses, ships, trees, &c., by lightning, is owing to their being imperfect conductors; and consequently arresting or retarding the fluid, until it tears, burns, and fuses them. Caloric repels its own particles, and is attracted by ponderable matter; the same is true of electricity. They are also both conducted by the same materials. Caloric and electricity are both attracted by points. Caloric enters slowly into a smooth metallic body, but rapidly into one which presents a great many points. They are both produced by friction and by pressure.

96. That caloric, or electricity, is greatly concentrated on quitting a mass of vapor in the form of lightning, is proved by the fact, that a single spark or streak causes a general precipitation of rain; from which we are authorized to infer, that its force and velocity are owing to its condensation. When greatly compressed in the form of steam, the velocity of its explosion is instantaneous.

97. Flannel, worn next the skin, acquires electrical properties, and gives out sparks freely on rubbing it. Signor Matracci, of Forli, found by experiment, that when glass plates were exposed to the solar rays, they became electric if no clouds intervened. If a Leyden jar could be charged with electricity by the solar rays, with a prism, or a burning glass, the experiment would be still more conclusive.

98. The rapid motion of electricity has been considered as an argument against its identity with caloric: but we have

a wire of great length be extended, having one end connected with an Electrometer, the hand of the galvanometer will be retarded on the sudden application & withdrawal of the wire of a taper at the other. —

proved that the rapidity of its motion, is owing to its accumulation. When caloric is greatly accumulated in iron, as when it is brought to a white heat, it is radiated with great velocity, carrying off with it portions of the metal in a state of incandescence, or sparks, with a rapidity resembling the electric spark. The spark from flint and steel is produced by the percussion of hard bodies, and moves with great rapidity.

99. Electricity can be drawn from a prime conductor gradually, by means of a sharp metallic point, without producing a spark, when it becomes a constant current while the cylinder is turning:—and if directed on the forehead it produces the sensation of a pleasant breeze. If the human body be insulated while the current is passing into it from the prime conductor, it is very soon saturated, when the fluid runs over—the hair stands erect, until the body is brought near to a conductor, when it passes off, and the equilibrium is restored.

100. It cannot be contended, that the velocity of the electric fluid is greater than that of the solar rays. Caloric, like electricity, moves with a velocity proportioned to its intensity at its source. Caloric and electricity, in all their forms, produce the same light. The combustion of charcoal by a current of galvanic electricity, causes the most vivid light in nature, except that of the solar beams. When decomposed with a prism, they present the same elements.

101. We have been thus particular in elucidating the subject of electricity, in connection with caloric, from a *deep conviction of its importance*—and because we believe that it is not rightly understood. It is contrary to that simplicity which characterizes all the operations of nature, to make a primary distinction between them: consequently it is

unphilosophical to consider them as separate branches of pneumatology. Though we do not pretend to understand *how* it is, that caloric in all cases exhibits electrical phenomena, we have proved, that, independent of caloric, electricity has no existence.

102. We have no evidence that either caloric or electricity is ever visible, unless when combined with other matter in a state of expansion. There is no matter which does not become luminous when greatly expanded by this subtle element. The light of a candle is produced by the expansion of its combustible materials by caloric;—from which it follows, that light is composed of ponderable matter in a state of extreme diffusion.

103. Dr. Fusinieri found by experiment, that the electric spark drawn from metallic conductors, carries off with it a portion of the metal, in a state of fusion, or of incandescent molecules, whatever be the nature of the metal. Are we not authorized to infer from the above facts, that solar light is composed of the matter of the sun, so exceedingly expanded by caloric, as to become phosphorescent and imponderable? The expansion of solid matter into light by caloric, is, perhaps, the nearest approach to the ultimate division of matter, that we can conceive.

104. In so large a body of matter as the sun, is there not caloric enough constantly evolved, to bear off a portion of its matter through all the illimitable fields of space? It is not a little surprising, that the production of light by common combustion, did not long ago lead philosophers to this conclusion. They generally agree, that in light, caloric is combined with

some other material. In the case of a burning candle, what is it; but the diffusion of its combustible matter!*

105. What shall we say of those theorists, who deny the materiality of both light and heat?—who reject the evidence of their senses:—and who will not believe in the existence of any thing which cannot be weighed with our imperfect balances, like a loaf of bread. They know that caloric increases the volume of matter:—they also know that light is decomposable, and that it produces chemical changes on other matter; yet they maintain, that they are merely the result of motion among the particles of bodies. If asked what causes this motion among the atoms of ponderable matter, they are silent. If they are referred to the elastic power of caloric in a steam engine, they are equally at a loss. Admitting that caloric is the effect of motion among the particles of water in the boiler, *what causes the motion?* It is something which produces palpable and visible expansion;—therefore, must be matter.

106. Dr. Young, and Mr. Herschel, jun., tell us, that light consists of the periodic movements of an elastic medium which pervades all space—regularly recurring at equal intervals, no less than five hundred millions of millions of times in a single second. That it is by such movements communicated to the nerves of our eyes, that we see:—nay, more, that it is the frequency of their recurrence which affects us with the sense of the diversity of colors; that, for instance, in acquiring the sensation of redness, our eyes are affected four hundred and eighty-two millions of millions of times; of yel-

* It has been ascertained by the experiments of M. M. Nobili and Melloni, that phosphorescent matter is always accompanied by caloric, though in small proportion. (*See Annales de Chim. et de Phys.* for October, 1831.)

lowness, five hundred and forty millions of millions of times; and of violet, seven hundred and seven millions of millions of times per second.*

107. The question naturally arises, what is the elastic medium to which these distinguished philosophers refer, if it be not caloric?—and what is the cause of the rapid periodic movements, to which they attribute the sensation of different colors, admitting that such periodic movements do exist? We doubt very much whether the above theory will stand the test of rigid analysis. It reminds us of Mr. Herschel's definition of abstract science, contained in the second chapter of his really beautiful Discourse on Natural Philosophy. He says, "that abstract science is independent of a state of nature—of creation—of every thing in short, except memory, thought, and reason." We confess ourselves unable to comprehend the meaning of such definitions.

108. Nothing is more surprising than that such men as Count Rumford and Sir Humphrey Davy, should have doubted the material and independent existence of caloric. Sir Humphrey Davy supposed, that caloric was often produced by the combination of vitreous and resinous electricity—in which opinion he has been followed by Winterl and Oerstedt.

109. That the reader may fully understand the views of Sir Humphrey Davy in regard to the nature of caloric, we shall present the following quotation from his Chemical Philosophy, page 52; observing at the same time, that we think

* See a Discourse on the Study of Natural Philosophy, by J. F. W. Herschel, Esq., F.R.S., and Young's Lectures on Natural Philosophy, Vol. 2, p. 627.

it the most inconclusive reasoning contained in his valuable work, and altogether unworthy of so great a man.

110. "When the temperature of bodies is raised by friction, there seems to be no diminution of their capacities, using the word in its common sense; and in many chemical changes connected with an increase of temperature, there appears to be likewise an increase of capacity. A piece of iron made red hot by hammering, cannot be strongly heated a second time by the same means, unless it has been previously introduced into a fire. This fact has been explained by supposing that the fluid of heat has been pressed out of it by the percussion, which is recovered in the fire; but this is a very rude mechanical idea. The arrangements of its parts are altered by hammering in this way, and it is rendered brittle. By a moderate degree of friction, as it would appear from Rumford's experiments, the same piece of metal may be kept hot for any length of time; so that if heat be pressed out, the quantity must be inexhaustible.* When any body is cooled, it occupies a smaller volume than before: it is evident, therefore, that its parts must have approached towards each other. When the body is expanded by heat, it is equally evident, that its parts must have separated from each other. The immediate cause, then, of heat, is motion, and the laws of its communication are precisely the same as the laws of the communication of motion."

111. "Since all matter may be made to fill a smaller volume by cooling, it is evident that the particles of matter must have space between them; and since every body can communicate the power of expansion to a body of a lower temperature;

* It is certainly inexhaustible while any of the metal remains to be condensed by the pressure and friction.

Water in 100° Fahr. for the higher degrees down to 40° Fahr. continually occupies less & less space; but on cooling below 40° continues to expand with each degree of heat.

that is, can give an expansive motion to its particles, it is a probable inference, that its own particles are possessed of motion; but as there is no change in the position of its parts as long as its temperature is uniform, the motion, if it exist, must be a vibratory or undulatory motion, or a motion of particles round each other."

112. We have called the attention of the reader to this passage, because it has influenced the opinions of many other writers both in England and in this country; and because we think it fundamentally erroneous.

113. A remarkable proof of the *mechanical force* of caloric was exhibited the other evening in this city, while we were writing about it. On the 7th of May, about eight o'clock in the evening, the porter and victualling house of Mr. Woodward, 553 Grand Street, was struck by lightning, and considerable injury done to the wall and property. Thence it passed off across the street in an oblique direction, and struck the house of Mr. Sweesey, corner of Mangin and Grand Streets, entering near the eaves under a dormant window, which was shivered to *atoms*; while a lady who sat near it happily escaped unhurt. In its passage through the house, it overturned a bedstead and bed completely upside down, injured the furniture, and upset a barrel of pickles in the lower part of the house. The hole which it made in entering was nearly as large as a barrel. (*Vide New-York Courier and Enquirer.*)

114. We have taken this general view of caloric, for the purpose of showing the various appearances which it exhibits, under different circumstances. There are strong reasons for believing, that the aurora borealis and australis, is one of the

forms of caloric, which is given out by the upper current of the atmosphere, as it passes to the poles.

115. It is a well known law, that all matter gives out caloric, in passing from a rarer to a denser state; and we know that the density of the atmosphere greatly increases as we advance from the lower to the higher latitudes. We also know that the atmosphere, like all other bodies, owes its bulk to caloric. Hence it follows, that caloric must be given out, by the atmosphere, as it passes from a rarer to a denser state. M. Hansteen says "that it is a matter of common observation, in the arctic regions, confirmed by long experience, that the aurora borealis is accompanied by intense cold, especially after a mild day. He adds further, that while the auroræ are streaming, the sky becomes opaque or misty. He thinks that the aurora takes from the transparent aqueous vapor a portion of its caloric, and that it first becomes luminous on passing out of the atmosphere." M. Hansteen also states, that the auroræ are accompanied by an increase of magnetic intensity—that, when they are vivid, the horizontal needle is restless, quivers, and varies from three to five degrees from its ordinary place. (See *Edinburgh Philosophical Journal*, Vol. 12, p. 89.)

116. It is not a little surprising that M. Hansteen was not led by these facts to the theory above suggested. He considers the aurora as "probably the result of a struggle of powers put in activity by the variously constituted substances composing the mass of the earth, which we may one day, perhaps, learn to know,"—"That it decomposes the aqueous vapor of the polar atmosphere, thus producing the polar fogs"—from which it is evident that M. Hansteen's views of this singular phenomenon were vague and indefinite.

117. Notwithstanding the amount of caloric given out by the upper equatorial currents as they pass to the poles, very little effect is produced by it in moderating the climate, as it *escapes into the vacant regions above*—where not being compressed by the atmosphere, it expands like the electric spark in an exhausted tube, into broad bands or zones and columns—filling the sky with halos, or crowns of lambent light or undulating coruscations.

118. It is highly probable that the auroræ are formed in the upper and rarefied regions of the atmosphere—and that the different apparent heights of the columns are owing to their different distances from the point of observation.

119. It is worthy of notice, that the northern lights are most numerous and vivid during the long polar night, while the cold is most intense, when the upper current from the equator in its passage to the pole is greatly condensed ; and that they are then exhibited in much lower latitudes than during summer.

120. It is stated by Sir W. E. Parry and by Captain Scoresby, that during winter in the high latitudes, the auroræ were discovered more frequently south than north of Spitzbergen and Melville Island—from which we may conclude, that they are rarely formed beyond the latitudes of greatest cold ; because the atmosphere arrives at its maximum density at the limits of greatest cold.

121. It is also an important fact corroborating this view of the subject, that they are seen in lower latitudes in the middle and eastern portions of America, than on the western ; which are known to be considerably colder than the western, in the same latitudes, which is owing to the greater amount of atmo-

spheric vapor which is brought from the Pacific and Atlantic oceans by the prevalent west winds of the middle latitudes, and which gives out caloric during its condensation and precipitation on the western coasts. Hence, the greater amount of rain which falls on the western coasts of America and Europe, than on the middle and interior portions—hence, also the dryness of our west winds in the United States, east of the Rocky Mountains ; having deposited their vapor on the western side before reaching the interior. These facts enable us to understand why *our* west winds are dry—while in England and France they are wet, and east winds dry.

122. The aurora is seen much oftener in Vermont (between latitude forty-two and forty-four degrees N.) which is a cold mountainous state, than in France or England, though they are much farther north. General Martin Field has recorded in the American Journal of Science, that during the year 1830-31, the aurora was perceived on fifty-six nights ; and that during ten years previously it was observed eighteen nights on an average, annually, at Fayetteville, Vt.

123. We have been asked why the auroræ are not continually formed, as the atmosphere is perpetually flowing from the tropical to the higher latitudes ? We might as well be asked why there is not perpetual thunder and lightning while the atmosphere is charged with vapors moving from the sea over the land ? The condensations which occur in both cases are temporary and unequal, and depend on the relative temperatures of different aerial masses. When the upper current of warm atmosphere charged with vapor, comes in contact with the cold air of the polar regions, it gives out a large portion of

caloric, and the auroræ are vivid ; but when the condensation is less considerable, the caloric is given out imperceptibly.

124. The aurora is probably given off during the condensation of the upper equatorial current, with the vapor which it contains, in a mode similar to the evolution of silent lightning of a summer evening, which produces a lambent light, much more like the aurora than common lightning. It is highly probable, that the electric fluid is nearly all given out before the upper current reaches the centre of maximum cold, which explains why the aurora is less brilliant at Melville Island, than at Bear Lake, the Shetlands, Orkneys, &c. It also explains why in the coldest regions as at Port Bowen, Winter Island, &c., the magnetic needle was not sensibly affected by it, as in the United States, and in the north of Europe ; and why in the former places it was almost always seen by the British navigators southward of them.

125. Siberia, Lapland, and the Norwegian Alps, are distinguished by the frequent display of this beautiful meteor. It is said by Bergman "that persons travelling over the high mountains of Norway have been enveloped in it." It is also stated by Captain Cook and other voyagers, that it is frequently seen in the southern hemisphere, south of Van Diemen's land, and off Cape Horn, where the cold is excessive.

126. We have said that caloric is the source of life and motion in organized beings. Whether this opinion be well or ill founded, it has been maintained by many of the most wise and distinguished philosophers of both ancient and modern times. Heraclitus taught that "fire was the primordial principle of the generation of all things." It was the opinion of the Pythagoreans "that heat or fire was the principle of life,

animating the whole system of nature, and penetrating all the elements."

127. "The Platonists likewise held fire to be the immediate natural agent, or animal spirit; to cherish, to warm, to enlighten, to vegetate, to produce the digestions, circulations, secretions, and organic motions in all living bodies, animal and vegetable."

128. "Hippocrates, in his treatise on diet, speaks of a strong but invisible fire, which rules all things without noise, and is never in repose; which is the cause of motion, change, growth, diminution, &c., which actuates and animates the whole world." (*See Bishop Berkley's Siris.*)

129. That there is a subtle vivifying principle disseminated throughout nature, and which is intimately connected with caloric, would appear from the effect of cold on the various tribes of animal and vegetable existence.

130. Who has not rejoiced, after a long and dreary winter, at the return of warm and genial spring, when all nature seems regenerated, and bursts forth into a new existence, under the enlivening influence of the solar rays? Rich verdure clothes the fields and forests. Sweet scented flowers spring up on every side, filling the air with delicious odors. The birds break forth into song, and all nature resounds with gladness and melody. But in the dreary regions of perpetual congelation, no sounds of life are heard; an awful stillness reigns—and nature seems to have lost the power of production.

131. We know that life cannot exist without a continual supply of atmospheric oxygen. We also know that oxygen undergoes a chemical change in the lungs by respiration—that it unites with carbon—and that caloric is developed

during all its combinations with other matter. We are not to suppose, however, that atmospheric oxygen is absorbed by the lungs, and conveyed into the circulation by respiration. It is the *latent caloric* of oxygen which warms the heart, and stimulates it to send the blood throughout the system.

132. When treating of galvanic heat, we observed, that its energy was proportional to the extent of oxidation of the metallic plates ; so, in living beings, the animal heat imparted to them by respiration, is proportional to the amount of oxygen consumed: which must depend on the size and activity of the respirable organs. From the lungs it is conveyed with the blood to all parts of the system by secretory action. The capillary vessels themselves, being vivified by this element, modify the blood into different substances, according to their structure, health, disease, &c.

133. In birds the animal heat is higher than in man and quadrupeds ; while in cold blooded animals the temperature is low in proportion to the diminished size and activity of their respirable organs. In vegetables, whose respiration and circulation are irregular, the temperature varies with the season of the year, and the state of their foliage or lungs.

134. Dr. Wilson Philip performed the following experiments some years ago, for the purpose of ascertaining whether galvanism and the nervous fluid were identical. He divided the eighth pair of nerves, which are distributed to the stomach and lungs, by incisions in the necks of several living rabbits. After the operation, the parsley which they ate remained without alteration in their stomachs ; and the animals, after evincing much difficulty of breathing, seemed to die of suffo-

cation. But when in other rabbits similarly treated, a moderate current of galvanic electricity was transmitted along the nerve, below its section, to a disc of silver, placed closely in contact with the skin of the animal, opposite to its stomach, no difficulty of breathing occurred. The voltaic action being kept up for twenty-six hours, the rabbits were then killed, and the parsley was found in as perfectly digested a state as that in healthy rabbits fed at the same time; and their stomachs evolved the smell peculiar to that of a rabbit during digestion. The experiments were several times repeated, with similar results. (*See Philip's Inquiries into the Laws of Organic Life.*)

135. He also proved,* that, whatever the nervous fluid may be, it is received into the system by respiration. He rendered rabbits insensible by a blow on the occiput; the spinal marrow and brain were then removed, and the respiration kept up by artificial means—when the motion of the heart, and the circulation, were carried on as usual—showing, that while caloric was imparted to the system by respiration, the mutilation and destruction of the most important organs, did not destroy life.

136. One thing is certain: that innumerable forms of life spring from, or at least accompany the presence of caloric; while its absence is always attended by the entire extinction of life. Hence it would appear unphilosophical, to call in the aid of some other unknown imponderable aura as a vital principle, when the agency of caloric, united (though we know not precisely in what manner,) to the various forms and combinations of matter, explains the phenomena quite as well.

* If his experiment was fairly performed.

137. There can be no doubt, whatever the vital principle may be, that it is united with oxygen and imparted to the organism by respiration. Now if it be contended that it is not caloric, but some other imponderable essence, united with oxygen, the difficulty is still the same, inasmuch as it fails to reanimate the dead body, though oxygen be poured into the lungs by artificial respiration:—owing to the cessation of those actions by which atmospheric air is decomposed in the lungs, and the caloric of its oxygen given out and distributed through the system. I would ask any physiologist this simple question, *could life be supported by respiration, if it were possible to respire oxygen without caloric?* It is obviously necessary to the existence of atmospheric air.

138. My friend, Dr. Caldwell, objects to caloric as the primordial principle of life, because its application to a dead body, will not restore irritability and sensibility. The reason is, that after the organic relations have been deranged, the blood coagulated, and the heart paralized, caloric cannot be circulated through, and combined with the organism in the same state and proportion it was by respiration, secretion, &c.

139. The states and affections of caloric are infinitely diversified by the various modes of its combination with ponderable matter. That the lower orders of life are often constituted by its union with dead animal and vegetable matter in a state of decomposition, can scarcely be controverted. It is notorious that thousands of species of animalcules, insects, and cryptogamous vegetables, such as molds, conservæ, &c., spring from the putrefactive process, under the vivifying influence of solar heat: so that irritability, the fundamental property of life,

seems to result from the union of this subtle element with ponderable matter in a state of decay.

140. He who wishes to behold the simplest gradations of life, as they emerge from a state of inanimate existence, has only to enter some deep mine, where unmolested by winds and changing temperature, molds and mosses cover the damp walls. Their fragile and gossamer filaments seem to be composed chiefly of water : a breath will destroy them. Now it is an interesting query, whether these simple and evanescent forms of life have any other origin than spontaneous production. If they have, the evidence is beyond our scrutiny. How stupendous that Wisdom which has so ordained the laws of nature, that teeming life, springs from death !

"Throughout the air, the ocean, and the earth,
See matter quick, and bursting into birth."

POPE'S ESSAY NO MAN.

141. The truth is, that we live, move, and breathe constantly, in an atmosphere of unseen, but living fire. It is that which gives beauty and lustre to the blue empyrean dome—which dissolves and suspends the waters of the ocean on high—and which lets them fall in "fruitful showers to cheer the plains below." It is the active spirit of the storm and tempest—while it clothes the fields with living green, and causes all nature to rejoice.

142. Whoever unfolds aright, the grandeur and harmony of these manifestations of Infinite Wisdom, may be said, in the language of the eloquent Galen, "to chaunt a solemn hymn of lofty adoration to the great Author of the universe."

143. Observations were made with the microscope some years ago in France, which led some philosophers to adopt

the ancient doctrine, that all the elementary atoms of matter were alive—that they were composed each of separate, moving animalcules,—In short, that all nature was alive. Now there can be no doubt that the atoms of all matter are more or less in perpetual motion, caused by the transitions of caloric from one portion, to another. These chemical motions were probably mistaken for animalcular movements.

144. It is self evident that oxygen which supports combustion by giving out caloric, is also the supporter of animal life. When the oxygen of the atmosphere is inspired, it is charged with caloric positively—when expired, in combination with carbon, it is negative ; having imparted a portion of its caloric to the blood. The same thing is true in every case of oxidation or combustion, respiration of plants, &c. This is a law of vast importance, and explains almost every chemical combination which takes place throughout matter.

145. How is it that carbonic acid gas, when inhaled, destroys animal life ? Is it owing to the insufficient supply of caloric it affords ? It cannot be by a poisonous operation, because it is formed continually in the lungs, and is therefore in perpetual contact with them. It must be owing to the fact of its having lost that portion of latent caloric, which is necessary to vital action.

146. We have endeavored to prove that caloric is the cause of capillary and cohesive attraction—that its existing in different states in different elements, is the cause of chemical attraction, and that its unequal distribution in different bodies, causes an attraction between distant, as well as proximate masses.

147. To say that it is the bond of union between the hea-

venly bodies, might be considered too bold a stretch of generalization. It must be acknowledged, however, that the sun is one million times larger than the earth. If then, the sun contains one million times as much caloric as the earth, he must be *positive* in relation to all the planets and comets—while they are negative in relation to him. Sir Isaac Newton maintained, that there must be some connecting medium between the celestial bodies by which they are retained in their orbits, which he called “ether,” and which he supposed was more subtle than light. Does not caloric answer to this subtle medium?* Does it not extend from the centre, to the circumference of the universe? Is it not the cause of all the motions and transmutations of terrestrial matter?—of decomposition and re-combination—of secretion, nutrition, growth, &c? Is it not the semperviving energy of universal nature?

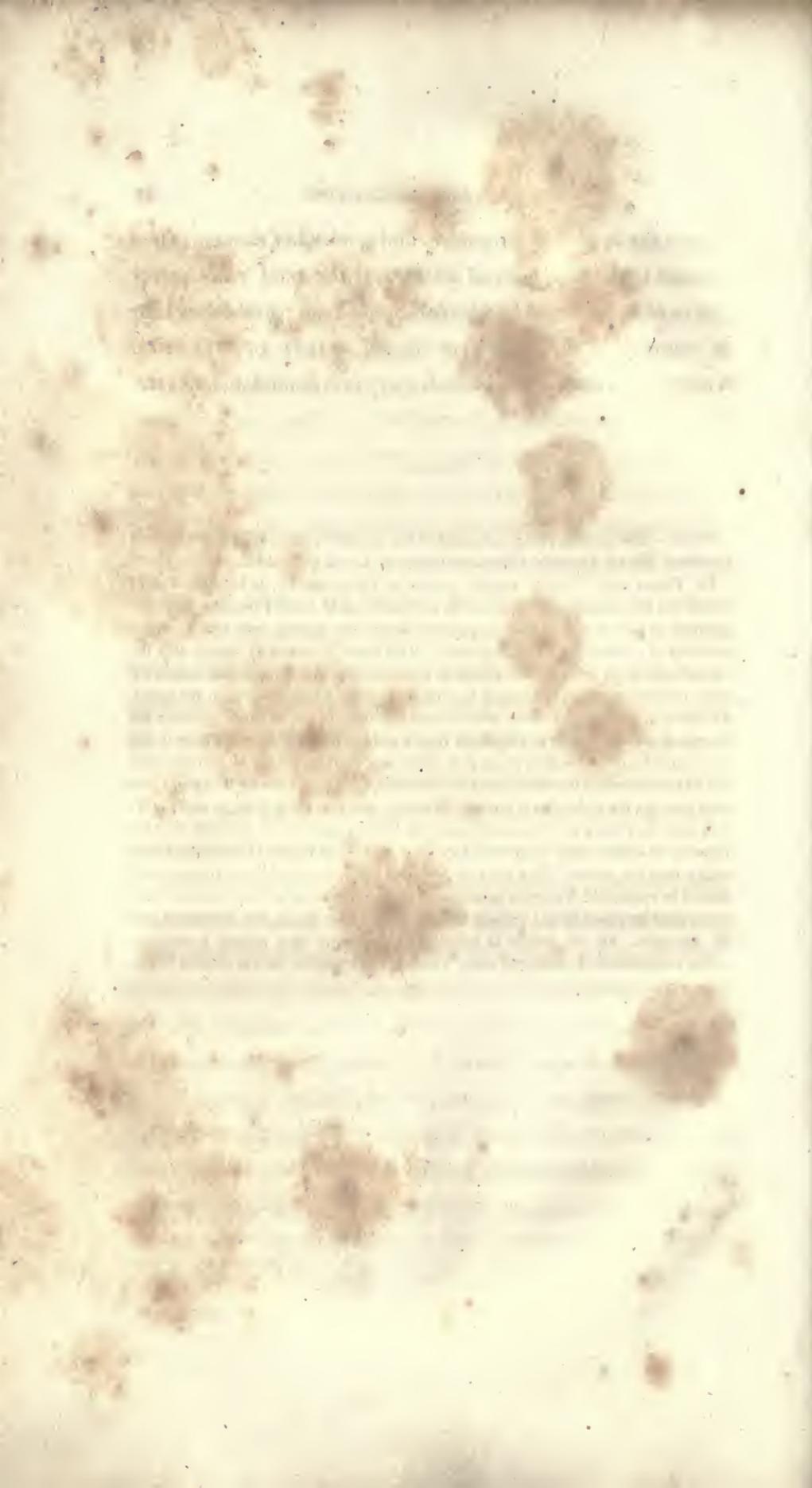
148. If the facts and principles which we have thus endeavored to unfold, be founded in truth, we can perceive no limits to their application. They are intimately connected with all the phenomena of living and dead matter, and therefore with every department of human knowledge. The philosophy of chemical affinity is still in its infancy, and presents a far more extensive field for discovery, than has ever yet been explored. He who enters upon it with enlarged views, and cultivates it with unwearyed application, will greatly extend the boundaries of science, and will derive from his labors more imperishable renown; than that of the conqueror who wades to a diadem, through the blood and tears of suffering humanity. To

* If we suppose caloric to be the cause of gravity, we must also suppose, that it is itself without gravity—otherwise we shall only explain the phenomena of gravity by itself, which would be absurd.

control the operations of nature, and render her elements subservient to the happiness of millions, is the most noble prerogative of enlightened and philanthropic man ; and raises him to communion with the ever blessed SPIRIT OF ETERNAL TRUTH, to whom be ascribed all glory and dominion, for ever.

NOTE.—The ensuing paragraph should have followed section 18 ; but we had not examined Doctor Turner's Chemistry until part I. was printed off.

Dr. Turner says "that the specific gravity of spermaceti oil, is less than that of water, but that its capacity for caloric is only half that of water ; because, the same quantity of caloric which heats a pound of water one degree, will heat an equal quantity of spermaceti oil two degrees." This experiment clearly proves, that the oil had previously more specific caloric in it than the water, and not that its capacity is less : therefore required less caloric to raise its sensible temperature than the water. He states in another part of his work, "that it is difficult to determine whether the increased specific caloric of solids and liquids at high temperatures, is owing to the accumulation of heat within them, or to *dilatation*," but, he believes "to dilatation." He has not informed us what causes the dilatation, which is evidently the effect of caloric between the molecules of ponderable matter, whether solid, fluid, or aerial. To complete the climax of our astonishment, Dr. Turner adds, "it is probable that the capacity of elastic fluids in general for caloric, is inferior to that of the liquids from which they are derived." Is it not high time that errors so palpable and fundamental, should be exploded ? The great principles of chemical science, seem to be less clearly understood by many of our present writers, than by Dr. Black, Dr. Crawford, and M. Lavoisier. On the subject of caloric and electricity, they contain a heterogeneous combination of truth and error, which it is impossible for the student to distinguish, or comprehend.



A NEW THEORY
OF
TERRESTRIAL MAGNETISM.

PART II.

In the preceding part of this Essay, we endeavored to show that capillary and cohesive attraction are owing to the unequal distribution of caloric, and to its *attraction for ponderable matter*—that the attraction of distant masses of vapor by mountains, clouds, &c., is owing to the same cause, operating on a large scale.

We also endeavored to trace the origin of atmospheric electricity, and to prove, that it was only one of the numerous forms of caloric—that it combined with water as caloric, and converted it into atmospheric vapor; but that when greatly accumulated, and given out rapidly, it exhibited electrical phenomena.

We further stated, that galvanic electricity was *another* modification of caloric—that it was evolved by the combustion or oxidation of metals in acids or alkalies—that according to the experiments of M. Pouillet, electricity is given out during all combustions—and that it is developed like caloric, by friction, by pressure, and by chemical decomposition—

that they both produce the same effects on ponderable matter—that they expand solids and convert them into fluids—that they convert fluids into gases—and finally, that by a still farther expansion of ponderable matter, they produce *light* of every description, from that of a candle, to the solar beams—and even that of the aurora borealis.

We also stated, in a hypothetical way, for the purpose of showing the *universality* of caloric, that it seemed to be intimately connected with the vital principle—and that it was probably the bond of union among the heavenly bodies. In short, that it was the cause of all the motions and changes which take place throughout matter.

We shall in the next place, endeavor to point out the connection between caloric and terrestrial magnetism. That our object may be distinctly understood at the outset, we shall lay down the following positions as the basis of our reasonings.

1. That there is an unequal distribution of temperature in the tropical and polar latitudes.
2. That the unequal distribution of land and water over the globe, causes unequal temperatures in given latitudes.
3. That a line passing round the globe from east to west, which divides its temperature into two equal portions, is the magnetic equator.
4. That the centres of greatest cold are the centres of magnetic attraction; and that the force of attraction is proportional to the intensity of cold.
5. That the prevalence of land in the tropical latitudes, produces a general elevation of temperature; while its predominance in the *higher* latitudes, causes a corresponding *reduction* of temperature.

6. That the magnetic needle is apparently operated on by two forces—one vertical, and the other horizontal; and that the horizontal, is exclusively the *directive force*.
7. That the vertical force, which causes the needle to dip, is probably equal on every part of the globe, when the horizontal force is quiescent.
8. That at the magnetic equator the dipping needle is horizontal—and that it dips gradually more and more, until we approach the magnetic poles, where it becomes vertical.
9. That the horizontal intensity decreases, as the dip increases, until we approach the regions of lowest mean temperature, where it vanishes, and the compass needle will not traverse, but remains in whatever position it is placed.
10. That there is more than three times as much land in Arctic America, as in Arctic Asia and Europe, attended by a corresponding reduction of temperature, and increase of magnetic intensity.
11. That there are *at least* two magnetic poles in each hemisphere of unequal intensities, and at unequal distances from the geographical poles.
12. That these poles are not stationary, but shift from east to west, and from west to east—also, from north to south, and from south to north.
13. That the unequal distribution of caloric in the tropical and polar latitudes, is the cause of magnetic polarity.
14. That the unequal distribution of land and water, causes an unequal distribution of temperature in given latitudes, is most clearly exemplified in the different zones of the American continent. Between the equator and the fortieth degree of south latitude, there is more than double the quantity

of land that there is between the equator and fortieth degree of north latitude, which causes an increase of temperature of several degrees in the southern hemisphere. Besides, there is more than six times as much land in North America between latitude 40° and 80° , than there is between latitude 40° and the equator, which is a powerful additional cause of diminished temperature in the northern portion of the western continent.

15. In conformity with this difference of temperature between the northern and southern portions of the American continent, we find the magnetic equator in latitude 7° south of the geographical equator, in Peru.

16. In the Pacific Ocean, two thousand miles farther west, in longitude 126° from Greenwich, where there is no land on either side of the equinoctial line, the magnetic equator coincides with it; but forty degrees farther west, where there are a great many islands south of the equator, the isothermal division of the two hemispheres is three degrees south of it.

17. When we turn to the eastern division of the globe, we perceive a striking illustration of the general fact, that large bodies of land in the lower latitudes greatly increase the aggregate temperature, and cause a deflection of the line of greatest heat to that side of the equator where the land is situated. For example; Arabia, Hindostan, and Southern China, are situated in the northern hemisphere, near the equator: while there is no land opposite to them in the other hemisphere, except New Holland and a few small islands, which causes the line of maximum heat to pass *several* degrees north of the equator, at unequal distances—from east longitude 25° to 180° .

18. In Africa, which extends far on both sides of the equator, they come together in 25° east longitude from Greenwich. Hence it appears, that the geographical equator is not the true isothermal division of the globe, which would be the case, if the whole planet were of uniform surface and elevation.

19. The centres of greatest cold are the centres of magnetic attraction. It has been clearly demonstrated, that there are at least two great centres of magnetic attraction in the northern hemisphere: one in the north of the American continent—and the other in the north of Asia; and that the attraction of the American pole is much stronger than that of the Asiatic pole. For example; the needle obeys the American pole over two thirds of the northern hemisphere, embracing the whole of North America, the middle and northern Atlantic, nearly all Europe, North Africa, and throughout the North Pacific to the West.

20. Let us now examine how far this polar attraction corresponds with the climate of North America.—From the thermometrical observations of Captain Franklin, Sir W. E. Parry, and Captain Ross, when in quest of a north-west passage, we learn, that the northern portions of the American continent are the coldest regions of the known world*—that the mean annual temperature at Melville Island, in latitude $74^{\circ} 30'$ is below zero; or, from twenty to thirty degrees lower than what had been assigned to the geographical pole, according to the formulas of Mayer and Kirwin.

21. When we reflect that large bodies of land are both heated and cooled down much more rapidly than bodies of

* Except, perhaps, New South Greenland.

deep water, we shall not be surprised at the burning heats of Africa, India, and South America ; nor at the intense cold of Arctic America and Asia. Captain Scoresby estimates the mean annual temperature of the Greenland Sea, in latitude 76° , at about 18° , which is nearly two degrees north of Melville Island. This island is almost always connected with the continent by ice—so that its climate is really continental.

22. The difference between the temperature of land and sea is obvious from the following facts. The sun's rays penetrate the ocean for several hundred feet, by which heat is diffused through an extensive mass, while they penetrate the surface of the solid land only a few feet, which thus becomes greatly heated during summer, and as rapidly cooled down by radiation during winter. For the same reason, the land is hotter than the ocean by day, and colder by night. The perpetual motion of the sea, preserves a uniform temperature. Thus, when its surface is cooled down to the temperature of 39° of Farenheit, the water is condensed, sinks down, and gives place to the warmer and lighter particles, which rise and take their place. Hence we perceive why in tropical latitudes the ocean is cooler than the land, and in high latitudes warmer than the land, especially during winter. When the ocean is covered with ice, which is a bad conductor, it cannot give out caloric to the atmosphere above it, which therefore assumes the character of a cold continental wind.

23. The vicinity of Greenland and Spitzbergen, which are islands of great extent, and very mountainous, must have a sensible influence in lowering the temperature of the Greenland Sea—from which we conclude, that if the terrestrial pole be surrounded with water, its temperature may be only a

few degrees lower, and perhaps not even as low, as that of Greenland and Spitzbergen—or Hudson's Bay. Captain Scoresby has estimated the temperature of the pole at about 10° ; while at Melville Island it is below zero, as already stated.

24. Were it not for the existence of Greenland and Spitzbergen, the temperature of the northern Atlantic would be still higher—and perhaps open every summer to the geographical pole. Notwithstanding the immense number of icebergs annually formed in the valleys of Greenland and Spitzbergen, which descend into the surrounding ocean during summer, and thus lower its temperature, we find that the cold is much less severe in latitude 80° , than in the interior of the continent in latitude 65° and 70° , from Hudson's Bay to Regent's Inlet.

25. Passing over as Professor Jameson has done, the pretensions of the Dutch whalers, who alledged that they had been carried by winds and currents as far north as the latitude of 88° , or even $89^{\circ} 40'$, we cannot reasonably doubt the well authenticated accounts of Wilson and Guy, who respectively advanced to the latitude of 83° , during the year 1754, and of Stephens, who advanced to latitude $84^{\circ} 30'$ about the same period. They all state, that the sea was open as far north of them as they could descry, and that the cold was by no means excessive.

26. "From all the above facts taken together, we are authorized to believe, that the mean temperature of the terrestrial north pole is considerably higher, than at the magnetic pole; because surrounded by water—while the magnetic pole occupies an interior continental position. It is worthy of notice, that the longer exposure of the terrestrial pole to the sun du-

ring summer, has a tendency to raise the temperature higher during summer than in lower latitudes—so as to dissolve the ice which had accumulated during the polar winter.

27. There are two interesting facts by which we are enabled to determine the position of the magnetic poles—one is, that over the magnetic poles, the dipping needle becomes vertical; and the other is, that the horizontal needle loses its directive power.

28. That there are two great centres of magnetic attraction in the northern hemisphere, was known upwards of two centuries ago. Their position and relative intensity, are of recent discovery. Sir W. E. Parry wintered a few degrees northwest of the American pole in 1819–20, and sailed nearly over it in Prince Regent's Inlet the following summer in latitude 72° , where his compass needles became useless. We shall presently see, that this is never the case, except about the centres of maximum cold.

29. Professor Hansteen, of Norway, has made and collected a vast number of observations in the north of Europe and Asia, for the purpose of ascertaining the variation, dip, and intensity of the needle, in those portions of the eastern continent—from which he conjectures, that the Asiatic pole is in latitude 85° north, and longitude 102° east of Greenwich.

30. Having thus ascertained with considerable accuracy, the positions of the two great centres of magnetic attraction in the northern hemisphere, we shall now endeavor to explain the cause of magnetic polarity. We have shown, that the magnetic equator is a line dividing the temperature of the globe into two equal parts. We shall next proceed to state the different positions assumed by the needle in different lati-

tudes. At New York, in latitude $40^{\circ} 42'$ and longitude 74° , west, a needle well balanced on its centre, having free motion, in a vertical plane, and afterwards magnetized, has an inclination or dip of its north end towards the centre of the earth about 73° , while at the magnetic equator, it is perfectly horizontal. In the southern hemisphere, the south end dips.

31. In assuming this position, it would appear that the needle is operated on by two forces; the one vertical, and the other horizontal—the former caused by the attraction of the earth, the latter by the unequal distribution of caloric in the tropical and polar latitudes. That the north end of the needle is attracted by the earth in this hemisphere, is evident from the fact, that when placed at right angles with the magnetic meridian, it assumes a vertical position; but when turned in the direction of the magnetic force, it rises. Now, whatever the cause may be, which raises the magnetic needle from a vertical to an inclined or horizontal position, must be the cause of polarity; and the angle of inclination must be the inverse measure of its horizontal intensity.

32. At the magnetic equator, both these forces act equally on both ends of the needle; the consequence of which is, that the needle assumes the horizontal position. When it is removed to the magnetic pole, or centre of maximum cold, there is no horizontal force exerted on it to raise it from the vertical position: from which it is obvious, that if there were no other force exerted on the needle than that of the earth's central attraction, it could never polarize.

33. It is admitted by nearly all writers on magnetism, that in the northern hemisphere, the north end of the needle is positive, while the south end is negative. In the southern

hemisphere, the south end is positive in the same way, while the end which points to the equator is negative in relation to it. We before stated, that in both hemispheres, the polar ends of the needle inclined towards the earth in proportion as we advance towards the magnetic poles. Now if the earth be negative in relation to the polar ends of the needle, they must be attracted by it, for the same reason that the opposite poles of a magnet attract each other, which, together with the diminished horizontal intensity, must cause the polar ends of the needle to dip.

34. Mr. Read, of Knightsbridge, observed, that when the atmosphere was transparent, lightning rods were charged with electricity by induction, the upper ends being negative, and the lower ends positive; while a portion of the rod towards the middle was neutral. (*See Thomson on Caloric and Electricity*, p. 446.)

35. However inexplicable this may appear, it is precisely analogous to what we find in the magnetic needle, and the analogy is a curious subject of inquiry. A dry atmosphere electrifies *negatively*, that end of the rod which is nearest to it, and *positively* the end which is furthest off. So likewise, the equatorial zone is certainly positive, yet those ends of the needle in both hemispheres, which are directed towards the magnetic equator are negative, while the polar ends are positive. Who is able to explain this?

36. In the preceding part of this essay, we proved that it was the universal tendency of caloric to pass from where it is plus to where it is minus,—that distant masses of vapor, unequally charged with caloric, attract each other, and are attracted by mountains, &c., until the equilibrium is restored,

when the attraction ceases. Now we know, that caloric is greatly accumulated in the tropical regions, and that it exists in comparatively small quantities in the polar regions—consequently, that there must be a perpetual flow of caloric in those directions in search of an equilibrium: from which we infer, that if the temperature of the equatorial and polar regions could be equalized, the horizontal or directive power of the needle would also cease.

37. It may be contended, that the passage of caloric from the tropics to the poles is not the cause of magnetic polarity, because during summer, the interior of the United States is frequently warmer than the tropical ocean, while the sun is above the horizon—and that, therefore, the calorific currents would be towards the tropics. It is true, that while the diurnal temperature of the magnetic equator, on the ocean, is about 83° , the thermometer often rises to 90° , and sometimes higher, at New York, Boston, and Philadelphia, in latitude 40° , 41° , and 42° . We should not forget, however, that during this period of high summer temperature at New York, it is about 32° at the magnetic pole; so that there is a much greater flow of caloric from New York to Melville Island, than from New York to the magnetic equator.

38. In accordance with this condition of things, we find, that the magnetic intensity is weaker during summer than winter, when the difference between the temperature of the equator and the magnetic poles is considerably increased; being from about 85° *above*, to 40° , or 50° , and even 58° below zero.

39. That invisible force which directs the needle, whatever it be, must be a material agent, every where present on the

globe ; but we have proved that caloric is every where present, and that it is unequally distributed in the lower and higher latitudes. It was demonstrated by Scheele fifty years ago, "that radiant heat passes through the air without heating it, and that no aerial currents, however strong, have any tendency to intercept it." (See *Thomson on Caloric and Electricity*, p. 131.)

40. It is highly probable, that a great portion of the earth's radiant heat passes upwards into the higher regions : it cannot be maintained, however, that caloric is radiated upwards only. A horizontal radiation was clearly demonstrated the other day, when the City Hotel was on fire, as it is in every case of combustion.

41. Perhaps it may be safe to state in general terms, that one half of the caloric received by the earth from the sun, escapes by radiation ; and that the remainder combines with surrounding bodies, and thus becomes latent. We know that a large proportion of solar heat is continually entering into solids and converting them into fluids and gases ; and that the balance passes off by radiation to those bodies which contain less of it. That portion of the matter of light which is not caloric, probably combines with the ponderable matter of the earth, and thus loses its phosphorescent properties, becoming a portion of common matter. Sir Isaac Newton asks the question, "are not light and common matter convertible into each other."

42. We have already stated, that the northern parts of our own continent are the coldest portions of the known world. That they are greatly colder than the north of Asia and Europe is demonstrable from the fact, that it contains more than three times as much land within the arctic circle, as Asia

and Europe. This fact, according to our theory, explains why the magnetic needle obeys the American pole over 240° of longitude, which embraces two-thirds of the northern hemisphere—while it points to the Asiatic pole over only 120° of longitude.

43. If the whole northern hemisphere were of uniform surface and elevation, its temperature would be also uniform in given latitudes; and its point of greatest cold would be at the terrestrial pole: but as the surface of the earth is diversified by land and water—by elevated mountains and deep valleys—by rocky hills and verdant meadows—by desert plains and by dense forests, its temperature varies greatly in the same latitudes,—hence, in the northern interior of America, the mercury falls to 50° and 58° of Farenheit below zero during winter; while on meridians surrounded with water, we find the temperature from fifteen to twenty degrees warmer in the same latitudes.

44. The existence of different magnetic poles or centres of cold in each hemisphere, situated at unequal distances from each other, and from the poles of the earth's axis, produce all the phenomena of magnetic variation, which it must be acknowledged, has hitherto been involved in the deepest obscurity. If the whole northern hemisphere were level and of uniform surface, there could be but one magnetic pole or centre of maximum cold, which would be at the geographical pole: consequently, the needle would always point in the direction of the geographical meridians, and there would be no variation of the compass. We should not be perplexed as we now are, with the oblique and devious character of the lines of no variation. The whole would be perfectly simple and intelligible

to the meanest capacity. The dip and intensity of the needle would be the same in given latitudes—and we should only have to account for the cause of its polar direction.

45. Perhaps no subject has more puzzled philosophers, than the unequal temperature of climates at different periods. Some few have doubted the fact, while others have endeavored to account for it in various ways. Dr. Brewster supposed that the centres of greatest cold, have a periodic revolutionary movement round the geographical poles—and that “the cold meridians which now pass through Canada and Siberia, formerly passed through Europe, causing the coldness of ancient Italy, as described by several Roman writers; who relate that the Tyber had been frequently frozen over—that snow lay on the ground for forty days at Rome—that the Euxine sea was frozen over every winter in the time of Augustus—that the Rhine and Rhone sustained loaded waggons, &c.” (*Edin. Ency., Art. Polar Regions.*)

46. In accordance with the facts which we have stated in relation to the cause of unequal temperature in given latitudes, it is difficult to understand with Dr. Brewster, how the “meridians of greatest cold,” which now pass through America and Asia, can revolve round the terrestrial pole, though we may conceive, without any violent hypothesis, that in former times, there was a third minor centre of cold in the neighborhood of Greenland and Spitzbergen—and that its influence extended for limited periods, over a large portion of western Europe. This appears to have been the case in modern times. The Greenland Sea, which was quite open and navigable from the eighth to the fourteenth century, became afterwards filled with ice, and so remained, according to dif-

ferent historians of Greenland, for nearly three centuries, so as to cut off all communication with Iceland and Norway, during the above period. An explanation of this singular phenomenon will throw much light on the difficult and important subject of terrestrial temperature.

47. It is not our present purpose to inquire how far the temperature of the globe has been altered during ancient epochs, by geological revolutions of its surface. Suffice it to say, that the fossil remains found imbedded in the transition and secondary formations throughout the American continent, from Alabama to Melville Island, demonstrate, that they were deposited on the floor of an ancient sea—and that its temperature was then much higher in northern latitudes, than at the present time. It is easy to conceive that a predominance of land in the tropical latitudes, and of water in the higher latitudes, would totally alter the distribution of heat throughout the globe—and that under such circumstances, a tropical temperature would extend to the arctic circle.

48. This view of the subject enables us to understand the diffusion of animals and plants in the older formations, whose analogues are now found only in the tropical regions. Mr. Lyell has termed this ancient condition of the globe, "a summer of the *great geological year*." He also maintains that the elevation of the western and eastern continents above that ancient sea, has produced a complete change of climate throughout the globe, and an entire extinction of numerous tribes of animals and vegetables, whose history is known only by their fossil remains.

49. To illustrate this subject still further, Mr. Lyell has supposed, that if in the progress of geological revolutions, the

dry land of the tropical regions should disappear, and high mountains, such as the Himmalehs and the Andes, should rise in the polar regions, (and he thinks it evident, that changes equally great have taken place,) the cold would be such as to destroy numerous tribes of animals and plants which now exist—and that we should then have what he terms, "*the winter of the great geological cycle.*" (See *Principles of Geology*, by Charles Lyell, F. R. S.,) where this subject is treated in a masterly manner. However fanciful and strange the above speculations may appear to those unacquainted with Geology, they are founded on a series of demonstrated facts, by a course of the most rigid philosophical induction.

50. We shall now return to the vicissitudes of climate which have marked the more recent periods of the earth's history.

51. It is highly probable that there is usually a greater barrier of ice accumulated in the latitudes of 80° and 81° around Greenland and Spitzbergen, than in the ocean farther north ; for this reason, that the field ice which is broken up during spring in the Arctic Sea, and floated by currents towards the south, is obstructed in its passage by the northern coasts of Greenland and Spitzbergen, where it accumulates, forming impassable walls of ice. This is rendered the more probable from the numerous accounts of Dutch and English navigators, engaged in the whale fishery, having advanced as high as $84\frac{1}{2}^{\circ}$, and some still farther, who all agree, that the sea was open as far as they could see from the mast head. Danes Barrington, Esq., a member of the Royal Society of London, has collected a mass of testimony on this subject, which it is impossible to disregard. When Captain M'Callam advanced as far as $83\frac{1}{2}^{\circ}$ in the year 1751, he found the sea

open, and would have proceeded farther but for the mate, who complained that the compass was not steady, when the captain reluctantly returned.

52. There can be no doubt, that there is more ice in Baffin's Bay, in latitude 73° ; or in any other portion of the sea, bordering on the continent, than there is farther north, where there is no land. Such is my conviction, that it is the land, and the icebergs formed in mountain valleys, which lowers the temperature of the sea, that I am strongly inclined to credit the accounts given by Barrington, of two Dutch whalers having proceeded as high as latitude 89° , where they found the sea quite open. It is much to be regretted that they made no observations with a dipping needle while in those high latitudes. They state, however, that the compass needle pointed to the south-west; as with Captain Parry in latitude 74° , and longitude 110° west, it pointed south-east to the magnetic pole.

53. It is impossible to assign any rational cause why during one period the northern seas should be open, and during other periods closed, without admitting the obstruction of field ice by the frozen coasts and by icebergs, on its passage to lower latitudes; by which the climate of the surrounding ocean acquires for a time a continental character. Captain Franklin saw icebergs aground in Baffin's Bay, in fifteen hundred feet water. If then we admit the occasional descent into the surrounding sea of a large number of icebergs, from the rivers and valleys of Greenland and the northern continent, we may easily comprehend how they would lower the temperature of the ocean, obstruct the field ice, and cause it to accumulate for thousands of square miles. When once the

mass became cemented, it would augment by every fall of snow and rain, until it became sufficiently strong to resist the power of the waves. During this condition of the Arctic seas, the polar winds would pass over them without receiving any warmth—and hyperborean rigors would extend to the middle latitudes.

54. Coinciding with this period of diminished temperature in the Greenland Sea, we find the most satisfactory evidence of a corresponding change of climate in England.

55. William Prince, Esq., of Long Island, who has published an exceedingly interesting History of the Vine, states, on the authority of several Roman and English writers, that it was introduced into England from Italy, at least as early as the year 280 of the Christian era, during the reign of Probus, if not earlier, as some historians have maintained. It continued to flourish in all the southern counties of England, until the reign of Henry the Eighth, when it began to decline; and about the year 1560, during the reign of Elizabeth, it had entirely ceased to mature its fruit, without artificial warmth. It is now the opinion of some horticulturists in England, that the climate is becoming adapted to its growth, and that it will again flourish as formerly.*

56. Corresponding with this opinion, there is an almost universal impression throughout the United States, that the winters are shorter and less severe than formerly. Mr. Jefferson, Dr. Rush, and Williams, the historian of Vermont, all relate, that in their respective states, the falls were later—the rivers froze later, and broke up earlier in the spring—that

* We are informed, that in the time of Strabo, it was impossible to mature the fruit of the vine in France, north of the Cevennes.

snows were neither so heavy nor so frequent as they were from the first settlement of the country to within seventy years ago. Volney says, it was a general opinion throughout the United States and Canada when he was here, that "the summers were longer, the winters shorter, snows lighter, and cold less violent, than in former times." Jefferson, Williams, and Volney, attributed this change to the clearing of the country, and to the general progress of cultivation. There can be no doubt that a cleared country is hotter during summer, than one covered with forests; but it is also colder during winter.

25

57. Corresponding with the milder character of the American climate for the last sixty or seventy years, we learn from Captain Scoresby, that the Greenland Sea is so far open at present, that he thinks the eastern coast might be approached every summer. It is easy to conceive, that while the Greenland Sea (which is only an immense strait, about 1000 miles wide, connecting the Atlantic with the Arctic Ocean,) was closed, it obstructed the annual passage of ice from the polar sea into the Atlantic, so that the Arctic Sea must have remained covered with ice for ages, giving a continental climate to a great portion of the polar ocean—and thus permanently lowering its temperature many degrees, by which the climate of Canada and the United States, must also have been rendered colder.

58. During the period of accumulated ice in the Greenland Sea, the winters were extremely cold in England. Dr. Webster states, in his History of Epidemics, that during the winter of 1683-4, trees of large size split open with the

frost—and that the same winter was excessively severe in America. (*See vol. 1, p. 204.*)

59. "The winter of 1779–80, was more severe in America than had been experienced for a great many preceding years. The mercury fell to twenty-six degrees below zero, on the 11th of January, at Hartford, Connecticut, in latitude $41^{\circ} 44'$." Dr. Webster also states, (the authority not given,) that "during the same winter, which was excessively cold in Britain, the mercury fell to forty-six degrees below zero at Glasgow;"—which we think very doubtful. It is highly probable, that the winters of 1830–1, and 1831–2, were the coldest that have been experienced in North America, since 1779–80.

60. Mr. Darby* has collected from the writings of the Abbe Rosier, M. Mezerai, and other authentic sources, a vast number of facts, which prove an increased severity of the climate of Europe, especially that of France, during the last three centuries. He gives examples of excessive winters, from the commencement of the Christian era to the fourteenth century—when the rivers and inland seas of Europe were covered with ice ;—but they were much less frequent and severe in the middle ages, than during the last three centuries, as the following statements, considered in connection with the state of the vine, renders extremely probable.

61. "A. D. 1433, frost commenced at Paris, the last of December, and continued during three months, less nine days—recommenced towards the end of March, and continued until

* See his *View of the United States.*

the 17th of April. The same year it snowed in Holland forty consecutive days.

"A. D. 1460, the Danube and the Rhone frozen."

"In 1468, wine was reduced to ice in France, and cut with an axe.—In 1544, a similar severity of cold occurred.

"A. D. 1493, the port of Genoa frozen.

"A. D. 1507, the port of Marseilles frozen in all its extent. Three feet of snow fell at the same city on the day of Epiphany.

"A. D. 1565, the Rhone was frozen to Arles.

"A. D. 1568, from the 11th to the 21st of December, the Rhone passed on the ice.

"The winter of 1570–1, from the end of November to the end of February, was so severe, that all the rivers, even those of Languedoc and Provence, were so completely frozen, that they were passed with loaded carriages.

"A. D. 1594, the sea at Marseilles and Venice frozen.

"A. D. 1603, loaded carriages passed the Rhone on the ice.

"The winter of 1621–2, the Venetian fleet arrested by the ice in the lagoons of Venice; in 1638, a similar event with the French gallies at Marseilles.

"A. D. 1645, the Swedish army passed from Holstein into Zealand on the ice.

"In the winter of 1655–6, the Seine was closed from the 8th to the 18th of December. It was again frozen, without interruption, from the 29th of December to the 28th of January. A new frost recurred a few days after, and continued until in March. (Bouillaud.) The ensuing winter, 1657–8, an uninterrupted frost from the 24th of Decem-

ber, to the 8th of February. Between the 24th of December and the 20th of January, the cold was moderate, but afterwards acquired an extreme intensity. The Seine was entirely closed. A slight thaw took place on the 8th of February, but the frost again recurred and continued to 18th. It was in 1658, that Charles X., king of Sweden, traversed the Little Belt with his army, artillery, caissons, baggage, &c.

"A. D. 1662-3. Intense frost at Paris, from the 5th of December to the 8th of March.

"A. D. 1676-7, continued and very intense frost from the 2d of December to the 13th of January; the Seine was closed thirty-five consecutive days.*

"A. D. 1684, the Thames, at London, frozen eleven inches thick, and traversed by loaded waggons.

"A. D. 1709, (perhaps the most intense season which has ever occurred within the range of history,) the Adriatic Sea, and the Mediterranean from Genoa by Marseilles to Cette, frozen. All the rivers and narrow seas of Europe frozen.

"A. D. 1716, booths erected on the Thames at London.

"A. D. 1726, sledges passed from Copenhagen to Sweden.

"A. D. 1740, the Thames, at London, again frozen."

62. The obstruction of the Greenland Sea by ice during the fifteenth, sixteenth, and part of the seventeenth century, by which the Greenland colonies from Norway and Iceland were

* It was from about the year 1560, until early in the seventeenth century, that a distinct centre of magnetic attraction existed between Greenland and Nova Zembla, which shifted irregularly, from east to west, about twenty-five degrees, in the course of one hundred and sixty years. During the above period, the needle pointed to Spitzbergen and the Greenland Sea, throughout the west of Europe, and not to the American pole, as within the last hundred and twenty years.

cut off from all communication with Europe, presents the longest period on record of ice accumulated in the Greenland Sea. It is quite probable, that during the age of the Cæsars, a similar accumulation existed between Spitzbergen and Nova Zembla, by which the climate of Italy, and perhaps of Europe generally, was rendered colder than usual, as before suggested. (See note, section 55.)

63. Captain Fisher, whose testimony is recorded by Barington, says, that it has been generally found by able and experienced seamen, that there is not near the quantity of fixed ice north of Spitzbergen, that there is south of latitude 80° as far as 74° ; which, he adds, is owing to its confinement in the strait between Greenland and Spitzbergen, and to the icebergs which descend from the valleys. From all the circumstances taken together, does it not appear obvious, that the English navigators in search of a north-west passage, would have had much better chances of success by proceeding round the American continent, than by attempting to force a passage through Lancaster Sound and Barrows' Strait, which are the coldest portions of the Arctic circle? X

64. It is highly probable, that the average temperature of the northern and southern hemispheres is nearly the same; the difference being, that in the northern hemisphere, the extremes are more general, owing to the larger amount of land, in the tropical and middle latitudes.

65. It is worthy of notice, that the prevalent and coldest wind during winter, in the middle and eastern parts of America, is from the north and north-west—right from the magnetic pole. Such is the severity of this wind, that it has on two or three occasions, reduced the temperature down to forty degrees

below zero, in the north of this state, latitude 44° , only fifteen or eighteen degrees higher than the maximum cold at the magnetic pole*—and even as far south as Nashville, three hundred and fifty feet above the ocean, in latitude $36^{\circ} 04'$, has reduced the mercury to twenty degrees below zero, during the winter of 1831–2.

66. Two opposite opinions have been advanced by two very able writers on the climate of the United States, both of which are true in part. M. Volney, who resided three years in the United States, maintained that the climate west of the Alleghany mountains was milder than that of the Atlantic states. He seems to have been led to this conclusion from the general mildness of the south and south-west winds, which prevail throughout the Mississippi valley nearly three-fourths of the year; while in the Atlantic states, the north-east wind prevails a considerable portion of the year.†

67. M. Volney explains the prevalence of the south-west wind which blows from the Gulf of Mexico, in the following manner. He supposes that the tropical trade wind is

* It is not often that the mercury falls so low in the United States; frequently it does not fall as low as zero in the middle states—so that we have presented rather the extreme range of temperature, than the general character of the climate.

† The cold damp atmosphere which often prevails during spring and summer in the Atlantic states of America, accompanied by north-easterly winds, is doubtless attributable to the influence of an unusual quantity of floating ice, off the coast of Labrador and Newfoundland, which condenses the vapor of the ocean, producing mist and fog on the north-eastern coast. During its continuance, it checks perspiration, and causes a general sensation of oppression, head-ache, and torpor of the system, physical and intellectual. In advancing south-westward, it deposits its moisture, and becomes comparatively dry and pleasant, in the valleys of Ohio and the Mississippi, which are screened by the Alleghany mountains, except during the winter months, when, from its greater strength, it advances across the mountains, and “covers the western country with snow,” or deluges it with rain, for one, two, or three days in succession, reaching as far as Mississippi, and Louisiana.

deflected by the Andes of Mexico, and turned from its western course up the valley of the Mississippi—that during spring and summer, it advances as far as Montreal and Quebec, and crosses the Alleghanies to the north-east." A circumstance which powerfully contributes to the strength and prevalence of this wind, is the greater rarefaction of the atmosphere over the heated land, than over the ocean during six months of the year, which alone would cause a wind from the ocean during the warm months. It is the meeting of this wind charged with vapor, with the colder north-east current, especially during autumn, which causes vast precipitations of rain, extensive vacuums, water spouts, whirlwinds, and hurricanes, which infest the Gulf of Mexico, and the southern portions of the United States. There can be no doubt, that the meeting of these winds, often produces a gyratory or vertiginous motion of the atmosphere, as described by Mr. Redfield.*

68. We should not overlook the effect of the caloric which is given out during aerial condensations, in producing *local rarefactions* of the atmosphere, which are always accompanied by wind, and a depression of the barometer. Such winds are often attended by precipitation, but not always—so that the barometer is not so much an index in regard to rain as to wind. Whenever it sinks low, we may be sure of a gale, though not always of rain.

69. Are not our hurricanes, which often run in narrow veins, and move with a velocity of from 100 to 120 miles per hour, caused by the sudden condensation of a mass of atmospheric vapor, by which a vacuum is produced, as it passes from the aerial to the aqueous state, so that the

* See American Journal of Science, April, 1831.

surrounding vapor rushes in with great force to restore the equilibrium? It is now generally conceded by those who know any thing about meteorology, that the aqueous vapor which floats above us, constitutes a distinct aerial medium from common atmospheric air—that it “percolates the latter mechanically, as water does a sponge:”* from which it may be inferred, that when the volume of aqueous vapor is diminished more than a thousand fold by giving out its caloric, the surrounding vapor rushes in to restore the equilibrium with a force proportioned to its elasticity, causing whirlwinds, tornadoes, &c.

70. In the valley of Ohio, at Cincinnati, latitude $39^{\circ} 06'$, the western winds prevail over eastern, in the proportion of six hundred and thirty-one, to three hundred and twenty-five. At New York, in the proportion of five hundred and eighty, to two hundred and seventy nine. The western winds almost always bring fair weather, if they continue any length of time—while the eastern and southern winds, coming from the ocean, generally bring rain.

71. Mr. Darby has collected a vast number of observations made in different parts of the United States, for the purpose of proving, that the climate is both colder and hotter west, than east of the Alleghany mountains. With the exception of the elevated portions of New York, and the New England states, which are excessively cold during winter, he has clearly established his position. He has shown that the live oak (*quercus semper virens*,) grows as far north as 34° on the Atlantic slope, while in the central basin of the Mississippi, in Louisiana, it extends only to $30^{\circ} 22'$ north—

* Daniell on the Atmosphere.

that the same is true of the large and dwarf palms. 'The sugar cane and orange, which cannot be cultivated to advantage above thirty degrees north in Louisiana, succeed well in South Carolina, Georgia, and Florida, three degrees further north. He also states, that in January 1812, snow fell at Opelousas, latitude $30\frac{1}{2}^{\circ}$, to a depth of eleven inches—and that in the latter part of December, 1814, the ponds and lagoons around New Orleans were frozen so as to admit half-grown boys to skate on the ice. (*View of the United States.*)

72. The vicinity of the Atlantic states to the ocean and to the gulf stream, moderates the severity of winter. The Alleghany mountains also protect them from the north and north-west winds. The expectation of many persons that the climate of the United States and of Canada, will be moderated by the removal of forest trees, is entirely fallacious ; which is proved by the intolerable coldness of the western prairies. During winter, and the prevalence of north-west winds from the icy summits of the lofty Chippewayans, and the elevated table land which borders their eastern base, they are exposed to Siberian rigors. Nor have they any mountain barrier to protect them from the northern winds which blow from the magnetic pole over Hudson's Bay, New Britain, and the Canadas.

73. After a careful examination of all the facts and arguments, we have come to the conclusion, that though the extremes of heat and cold are greater west, than east of the Alleghanies, there is more mild, clear, and agreeable weather in the Mississippi valley than in the Atlantic states.

74. We have frequently known the south-west winds to prevail in Kentucky, until the middle of December—and sometimes until Christmas, the weather is bland and delightful.

Nothing can exceed the soothing and gorgeous splendor of the autumnal sky, throughout the Mississippi and Ohio valleys.

75. We have just received accounts from Captain Nye, commander of the Liverpool packet ship York, that, on the 9th of June, 1833, a great number of icebergs were seen in latitude 43° N.—and from longitude 47° to 49° W. The thermometer has also been unusually low at New York, from the 12th of May until the 12th of June; averaging about sixty-eight degrees. The same low temperature prevailed the preceding May and June; owing to the same cause. A great number of vessels have been lost, at different periods, by being driven against icebergs, on their passage to Quebec, and in going to, and returning from Europe to our own ports.

76. The cholera first made its appearance at Quebec in May, 1832, and arrived at New York about the 27th of June. It is an important query in relation to this epidemic, how far its character was determined by the thermometric and hygrometric states of the atmosphere. M. Jannechen, of Moscow, in a work which he published on Cholera, states, "that its intensity in Russia was in a direct ratio to the hygrometric state of the atmosphere." This is what we should expect in all gastric and enteritic irritations. Whatever checks cutaneous perspiration, and causes a centripetal determination of the fluids, must favor the energy of internal irritations. And whenever a state of the atmosphere exists which favors an unusual flow of cutaneous perspiration, the type of whatever diseases then prevail, must be modified by the general thermometric and hygrometric constitution of the season. Does this not explain the prevalence of what has been termed the sweating sickness in England? When the cutaneous exha-

lents have been in a medium state of excitement, fever is produced by exposure to malaria, hot sun, and night air. If the malaria be mild, intermittents and remittents follow ;—if virulent, malignant, or yellow fever, malignant cholera, or dysentery, according to the previous thermometric and hygrometric state of the atmosphere. We hope to be able at some future period, to examine this subject more at large.

77. We have seen, that the cause of unequal seasons in the middle latitudes, is owing to the greater or less accumulation of ice in the northern seas. When they are open, the polar winds are tempered by passing over them, and we have mild winters ; but when they are filled with accumulated icebergs, and covered with field ice to a great extent, the winds pass to the lower latitudes with slight mitigation of severity, causing excessive winters. This is the *true rationale of our unequal winters.* They are not owing to the operation of distant planetary and cometary influence, but to the relative position of land and sea in the northern latitudes, and to the occasional obstructions of the Arctic ice in Davis' Straits, Baffin's Bay, and the Greenland Sea, by which it becomes greatly accumulated, until the unequal expansion of the upper and lower portions of ice, by the sun's rays, causes it to rend in a thousand fragments, when the waves of the ocean complete its final disruption, and it is carried by currents into lower latitudes and dissolved. Thus, Infinite Wisdom has provided, that extremes shall never long prevail. The order of nature presents a beautiful system of checks and balances, by which every evil incident to her economy, brings with it its own remedy.

78. We have thus explained in the most simple manner,

the strange variations of the Arctic climate, and shown how they modify the temperature of lower latitudes—sometimes causing mild winters, at other times excessive winters. We shall next examine the connection of these changes with the variations of the magnetic needle.

79. We have already stated, that if the whole earth consisted of a uniform surface, there would be but two magnetic poles, and that they would be the poles of the earth's axis: moreover, that the needle would be every where directed to these poles, and that there would be no variation of the compass. We stated further, that in the above condition of our planet, a magnetic needle perfectly balanced on its centre, would continue to dip uniformly, in advancing from the magnetic equator to the poles, where it would be vertical; and that the horizontal intensity would decrease uniformly on all meridians, from the magnetic equator, which would coincide with the geographical equator, to the poles, where it would be nothing.

80. If the above positions be correct, we perceive at once, that all the irregularities attending the dip, variation, and intensity of the needle, are occasioned by the unequal distribution of terrestrial temperature, which is caused by the unequal distribution of land and water, and by *unequal accumulations of ice in the polar seas.*

81. Many strange and improbable hypotheses have been invented by philosophers, to account for the progressive variation of the magnetic needle, the most prominent of which is that of Dr. Halley; and which has been embraced with some modifications, by M. Hansteen, of Norway.

82. Dr. Halley supposed the earth we inhabit to be a

mere external shell, enclosing towards its centre, a detached magnetic nucleus of a spherical shape, which he termed a terrella, and which he imagined was about 1150 miles in diameter; that it revolved with the external shell on a similar axis, but with a less velocity. He supposed both these spheres to be magnets, having each two poles; but the poles of the one, not corresponding in situation with the poles of the other. The difference of the periods of rotation of the two spheres, he conceived to be very small, yet sufficient to become sensible after the lapse of years, and to occasion a change in the relative situation of the two poles; hence would arise changes in the directions of their resulting actions, and corresponding changes in the variation of the magnetic needle. (*See Library of Useful Knowledge.*)

83. M. Hansteen's theory coincides¹ with that of Dr. Halley so far as this, that he maintained the existence of two magnetic poles in each hemisphere, within the earth, and that they revolve round the terrestrial poles, though in unequal periods of time.

84. We shall endeavor to show that there is no proof of a revolutionary movement of the magnetic poles, except their shifting a few degrees from east to west, or from west to east—and that in reality, such a movement is just as impossible as the revolutionary movement of the “cold meridians” of Dr. Brewster. The American pole has been nearly stationary for the last forty-five years; but with a slight shifting to the westward, within the last thirty years. We have no evidence that it has shifted more than five or six degrees within the last hundred and fifty years; nor that the eastern *south* pole has shifted to the same extent in the same time. How is it possible that any philosopher should contend, that the centres of

maximum cold of the American continent passed over to Europe eighteen or nineteen centuries ago, without a corresponding shifting of the land and sea? But we have no evidence, that any material alteration has taken place, in the relative position of land and sea for several thousand years. Hence, the cold meridians of the northern hemisphere, must have remained where they now are for indefinite periods of past time; and must *continue* to occupy their *continental* positions, until in the progress of geological revolutions, the present continents shall disappear, and others arise, to restore the balance of nature.

85. We have shown, that extraordinary accumulations of ice in the outlets of the polar seas, are sufficient to account for the existence of a minor focus of cold, the influence of which might extend throughout a great portion of America and Europe, and lower their temperature as in the epoch of the Cæsars. It is a remarkable coincidence, in perfect accordance with our theory, that at London and Paris, the magnetic needle was directed towards Spitzbergen, about midway between the American and Asiatic poles, during the period of greatest accumulation of ice in the Greenland Sea, when the Norwegian and Iceland colonies were cut off from Europe, and when the *vine ceased to flourish in England*; while at the same time, over the great continents of Asia and America, it pointed to their respective magnetic poles as at present: the plain inference from which is, that there must have been another pole at that time, near the meridian of London and Spitzbergen, which has since disappeared, as the Greenland Sea became open.

86. There are strong reasons for believing, that there is now more than one magnetic pole in the north of Asia, as M.

Biot describes two lines of no variation on the eastern continent; one on the meridian of Nova Zembla, and the other passing through the north-east of Siberia. No observations have been made by which we can determine the exact position of any of the magnetic poles, except those of Captain Parry in 1819 and 1820, when he passed a few degrees west of the American pole on the 8th of August, in Prince Regent's Inlet, latitude 72° , where the directive power of his compass needles ceased, remaining in whatever position they were placed. Captain Parry took no observation of the dipping needle there, but rightly supposes "that the dip would have been greater than at Winter Harbor," where it was $88^{\circ} 43'$.

87. Dr. Gilbert published a very ingenious work on magnetism, in the year 1590, in which he maintained, that the earth contained within itself a huge magnet, lying in a direction nearly coinciding with its axis of rotation, and that its power was collected at the poles of the earth. It is said that Kepler ranked this hypothesis among the greatest discoveries in the annals of science. (*See Lib. of U. Knowledge,— Article Magnetism.*)

88. The progressive and irregular changes which the variation and dip have undergone at different periods, and which had not been much observed at the time of Dr. Gilbert, totally preclude the idea of permanently fixed depots of magnetic attraction. It must be conceded, however, that in some respects, the earth acts as a great magnet; inasmuch as it imparts magnetism to substances placed in the direction of the magnetic meridian; and because it attracts the dipping needle towards its centre, when placed at right angles to the magnetic meridian, so as not to be influenced by the horizontal force. Allowing that iron is necessary to the production of

magnetism, which is not the fact, it is distributed in vast quantities *throughout* the earth as far as we can discover.* But that there are grand depots of magnetic iron in the polar regions, we have not the slightest evidence for believing. Nevertheless, this hypothesis has swayed the opinions of philosophers from the days of Gilbert to the present time—and has been a perpetual source of error among writers on magnetism, who seem to have taken it for granted, that the intensity of magnetic attraction increases from the magnetic equator to the poles.

89. An amusing example of the general prevalence of this belief among common seamen, is related by Barrington. In the year 1754, Captain Wilson commanded the Sea Nymph, a Greenland whale ship, when at the latter end of June, they sailed through floating ice from 74° to 81° north, but having then proceeded *beyond* the ice, they pursued the whales to latitude $82^{\circ} 15'$, where the sea was open as far as they could distinguish. Both Captain Wilson and Mr. Ware, the mate, had a strong desire to push forward towards the pole; on hearing which, the common sailors remonstrated, saying, "that if they should be able to proceed so far, the ship would fall into pieces, as the pole would draw all the iron work out of her," which caused the captain to relinquish his design. We have adverted to this circumstance for the purpose of showing how the great mass of mankind, philosophers not excepted, imperceptibly follow the footsteps of their predecessors, frequently without knowing why. A slight examination of facts will show, that the above doctrine has no foundation in truth—that in reality, the *directive* power of the magnetic needle *diminishes* as we approach the poles.

* Probably one fifteenth of the entire globe consists of iron.

90. It is to be regretted that such men as Count Humboldt and Captain Sabine, should have contributed to the propagation of this error. Humboldt supposed, that the magnetic intensity increased from the magnetic equator to the poles, because his compass needle performed a greater number of oscillations at Paris in a given time than at Peru;* notwithstanding the same needle performed an equal number of oscillations at Mexico, 7,400 feet above the sea, that it did at Peru; which ought to have convinced him, that the magnetic intensity did not increase from the magnetic equator to the poles.

91. Captain Sabine seems to have concluded that the magnetic intensity increases in going towards the pole, because the *dipping* needle performed a greater number of oscillations in Baffin's Bay and Davis' Straits than at London. We before suggested, that this was owing to the *diminished intensity of the horizontal force*, which in lower latitudes, counteracts the vertical force. Captain Sabine's experiments are inconclusive, as they were not fairly accompanied by observations in the same latitude with a horizontal needle.

92. There is an overwhelming mass of testimony in direct opposition to the conclusions of Humboldt and Sabine, furnished by hundreds of seamen and other individuals, who had no speculative views to sustain; and established by a long course of experiments by M. Hansteen, Captain Scoresby, and many other accurate observers. The most conclusive series of experiments ever performed to determine the magnetic intensity, is exhibited by M. Hansteen in the following

* If the observation was made, on the Cordilleras, ten or twelve thousand feet above the sea, we should *expect* a considerable diminution of magnetic power.

tables ; taken from the Edinburgh Journal of Science, volume IV., April, 1826 ; showing the time required for a compass needle to make 300 oscillations. We have also presented Dr. Brewster's explanation of M. Hansteen's tables, showing the intensity of the magnetic force in different parts of the earth's surface.—“ In order to determine the intensity of magnetism at different places, and consequently the direction of what he calls the *isodynamical magnetic lines*, or the magnetic lines of equal intensity, he had a magnetic needle of a cylindrical form, constructed with great care. This needle he entrusted to various philosophers, who counted the time in which *three hundred* horizontal oscillations were performed, in various parts of Norway, Sweden, Denmark, Prussia, Holland, France, England, and Scotland.. The greater number of these were made by Professor Hansteen himself, many of them by M. Naumann, several by M. Erichsen, and a considerable number by Professor Oerstedt, of Copenhagen, when he was travelling in England in 1823. Those which were made by this last philosopher in Edinburgh, on the 4th July, and at which we had the pleasure of assisting, were performed in the field behind Coates Crescent, and nearly at the intersection of Walker Street and Melville Street. These possess considerable interest, as being the most *westerly* of all that have yet been made.

“ The following table contains the result of these observations, the *first* and *second* columns containing the latitude of the place of observation, and its longitude from Ferroe ; and the *third* the number of seconds in which 300 oscillations are performed by the suspended needle.”

PLACES.		Lat.		Long. from Ferroe.		Time of 300 Oscilla- tions.
Berlin	-	52°	32'	31°	2'	760".03
Paris	-	48	50	20	0	753.03
London	-	51	31	17	34	775.34
Edinburgh	-	55	58	14	29	820.26
Liverpool	-	53	22	14	43	801.6
Oxford	-	51	46	16	24	779.8
Christiansand	-	58	8	25	43	820.3
Mandal	-	58	1	25	9	814.3
Tjøs	-					816.3
Carlscrona	-	56	7	33	13	785.3
Ystad	-	55	26	31	28	779.3
Szrim	-	52	7	34	48	748.1
Glogau	-	51	43	33	36	748.8
Carolath	-	51	46	33	37	752.7
Zelgos	-	53	11	32	48	759.7
Danzig	-	54	21	36	18	770.4
Marienburgh	-	54	2	36	42	766.0 *
Goslina	-	52	34	34	43	759.7
Aüstrin	-	52	35	32	40	762.4 *
Christiana	-	59	55	28	25	814.76
Friedrichshall	1819	59	8	29	4	821.7 *
	1822					830.3
Quistrum	1819	58	27	29	25	816.1 *
	1820					815.4
Hede	-	57	58	29	48	810.8 *
Gothenburg	1819	57	42	29	38	812.2 *
	1820					812.1
Quibille	-	56	47	30	30	791.6 *
Helsingburg	1820	56	3	30	23	791.1 *
	1820					790.0
Helfingöer	1820	56	2	30	18	789.8 *
	1820					784.6 *
Copenhagen	-	55	41	30	15	788.08
Friedrichsburg	-	55	56	29	58	785.9
Soroe	1820	55	27	29	14	790.6
	1822					790.4
Skieberg	-	59	14	28	51	826.7
Kongsberg	1820	59	40	27	20	845.4
	1821					839.3
						845.1

PLACES.		Lat.	Long. from Ferroe.	Time of 300 Oscilla- tions.
	1821			
Bolkesjö	-	59° 43'	27° 00'	837".8
Vik	-			859.5
Tindosen	-			834.9
Oernäs	-			836.8
Ingolfsland	-	59 53	26 28	834.6
Miland	-	59 56	26 36	829.1
Tind	-	60 00		833.4
Midböen	-			835.7
Rögsland	-			836.8
Nörsteböe	-	60 20	25 17	838.0
Holmekjärn	-	60 17	25 24	839.8
Maursäter	-	60 25	25 3	832.8
Eifjord	-			829.3
Ullensvang	-	60 20	24 18	852.6
Johnnäs-Tangen	-			840.7
Gjermundshafen	-	60 3	23 52	843.8
Kaarevigen	-	59 45	23 7	846.2
Findaas	-	59 45	22 54	838.2
Siggens	-			861.7
Folgeröe	-	59 48	22 56	824.2
Engesund	-	59 55	22 53	837.4
Bekkervig	-	60 1	22 50	840.7
Bratholmen	-	60 21	22 47	851.0
Bergen				839.5
Fort Friedrichsberg	-	60 24	22 57	850.1
Friedrichsberg	-			850.5
Lunggaards. See				849.3
Lyderhoru, 1255 feet				843.7
Lövstakken, 1524	feet			
Haugs	-	60 27	23 18	904.7
Bolstadören	-	60 32	23 43	845.2
Evanger	-	60 33	23 52	847.7
Vossevangen	-	60 38	24 10	845.9
Tvinde	-	60 42	24 11	850.6
Staleim	-	60 52	24 19	849.1
Leirdalsören	-	61 10	25 29	848.9
				856.3

PLACES.		Lat.		Long. from Ferroe.	Time of 300 Oscilla- tions.
Leirdals	-	61°	8'	25° 30'	852".2
Maristuen	-	61	2	25 54	855.3
Nyestuen	-	61	8	25 59	853.2
Vangs	-	61	6	26 23	845.6
Slidre	-	61	5	26 49	853.9
Tumlevold	-	60	51	27 38	843.7
Grans	-	60	22	28 12	842.3
Moe	-	60	14	28 11	848.3
Sundvold	-	60	4	28 7	842.6
Johnsrud	-	59	57	28 19	841.5
Hurdal	-	60	26	28 49	827.3
Trögstad	-	60	8	28 56	823.8
Sunbye	1822	59	36	28 35	826.8
Sooner	-	59	32	28 25	827.8
					828.1
Böe	-	59	7	29 7	823.2
Altorp	-	58	53	29 54	816.3
Oedskjölds-Moen	-	58	50	29 52	816.0
Elleöen	-	59	19	28 20	826.7
Godtskjär	-	57	26	29 43	809.9
Korset	-	58	49	27 12	824.5
Helgeraae	-	58	59	27 34	822.7
Stubberud	-	59	4	27 55	818.9
Solerud	-	59	21	28 9	826.5
Konnerud-Kollen					
	1823				875.5
Auestad	-	59	49	27 53	852.1
Bragernäs	-	59	49	27 53	848.6
Ravnsborg	-	59	52	28 17	820.5 *
Friedrichsvärn	1824	59	0	27 44	813.5
Friedrichshavn	-	57	27	28 13	808.1
Aalborg	-	57	3	27 36	806.0
Sporring	-				799.9
Aarhuns	-	56	10	27 54	796.0
Hovedkrug	-				798.3
Weile	-	55	43	27 12	793.9
Apenrade	-	55	3	27 6	786.4
Gehlau	-				787.9
Schleswig	-	54	31	27 15	783.0
					785.5

PLACES.		Lat.		Long. from Ferroe.		Time of 300 Oscilla- tions.
Remmels	-	54° 7'		27° 18'		783".0
Elmshorn	-	53 46		27 18		779.1
Altona	-	53 33		27 33		776.1
						774.9
Berlin	-	52 32		31 2		760.4
						759.9
Lübeck	-	53 51		28 21		776.2
Plöen	-	54 9		28 6		780.5
Preetz	-	54 13		27 57		779.0
Kolding	-	55 27		27 0		789.1
Odense	-	55 24		27 59		793.7
Buskerud	-					845.5
Johnsknuden	-					961.3
Skrimfjeld	-					891.3
Rolloug	-	59 59		27 5		844.0
Synhovedet	-					846.3
Eje	-	60 6		26 53		838.5
Ejesfjeld	-					831.2
Daglio	-	60 18		26 26		837.4
Torpe	-	60 40		26 47		841.5
Haavi	Juni	61 7		26 42		851.2
	Sept.					850.4
Urland	-	61 0		24 55		849.2
Voss	Juni	60 38		24 10		856.5
	Sept.					845.9
Age-Nuten	-					842.7
Vigör	-	60 18		24 5		850.7
Bergen	-	60 24		22 57		
Nyegaard	-					857.1
Flöifjeldet	-					854.7
Lövstakken	-					844.2
Friedrichsberg	-					851.7
Lindaas	-	60 43		23 8		843.5
Evenvig	-	60 58		23 8		850.6
Ytre-Sulen	-	61 4		22 45		852.1
Stensund	-	61 3		22 52		852.9
Pollefjeld	-					861.8
Askevold	-	61 24		23 7		861.1
Vilnäs	-	61 22		22 58		860.7
Sougesund	-	61 22		23 11		861.7

PLACES.		Lat.	Long. from Ferroe.		Time of 300 Oscilla- tions.
Alden	-	61° 22'	22°	50'	850".7
Bueland	-	61 17	22	44	851.2
Sveen	-				856.4
Quamshest	-				849.8
Förde	Juli	61 32	23	48	858.9
	Aug.				858.8
Jölster	-	61 35	24	10	848.6
Gloppen	-	61 51	24	6	861.9
Indvig	-	61 49	24	34	860.4
Horningsdal	-	61 59	24	33	862.6
Hälsylta	-	62 7	24	54	864.8
Nordal	-	62 18	25	13	870.3
Veblungsnäs	-	62 31	25	39	868.3
Fladmark	-				862.9
Nyestuen	-				862.7
Fogstuen	-	62 5	27	9	856.9
Jerkin	-	62 12	27	29	846.5
Foldal	-	62 7	27	57	855.5
Kongsvold	-	62 18	27	36	860.0
Drivstuen	-	62 26	27	41	858.0
Riise	-	62 31	27	41	858.1
					859.8
Näverdal	-	62 42	28	6	858.7
Stöa	-	62 32	28	21	860.4
Göra	-	62 35	27	2	862.1
Tofte	-	61 58	27	10	859.3
Vauge	-	61 51	27	4	860.8
Vinje	-	60 52	24	22	848.2
Nyestuen	-	61 8	25	59	852.1
Skougstad	-	61 10	26	12	853.7
Smedshammer	-	60 29	28	14	841.9
Sundvold	-	60 4	28	7	839.2

93. It will be evident to the reflecting reader, that these tables are incomplete, from the want of another column, giving the *elevations* above the sea at the respective places of observation.

94. It would have been much more satisfactory, could we have presented similar tables, showing the different intensities of the needle in different latitudes of the American continent. The principle to be illustrated, however, is equally proved, by observations made in any quarter of the globe.

95. It is a matter of almost universal notoriety among seamen, that the compass needle becomes sluggish in high latitudes—that its directive power is so weak, as to be greatly influenced by the local attraction of the ship's iron, which seldom occurs to any considerable extent in lower and warmer latitudes ; while at the magnetic pole it is nothing, the needle remaining in whatever direction it is placed, as was proved by Sir William E. Parry in the summer of 1819 and 1820. It is highly probable, that a dipping needle, placed in the direction of the magnetic meridian, would perform a greater number of oscillations in a given time near the pole than at the magnetic equator—for the obvious reason, that the *horizontal* force is greatly *diminished*—and not because the vertical attraction of the earth is increased. I performed an experiment with a dipping needle which convinced me at once, that the vertical attraction of the needle by the earth is nearly the same in every part of the globe (though I tried it only in New York,) when not counteracted by the horizontal force. On placing the needle at right angles with the magnetic meridian, it uniformly became vertical; but when placed in the direction of the magnetic meridian, always rose about 27° towards the horizontal position. Hence, I concluded that the dipping needle would make an equal number of oscillations in a vertical plane in all latitudes and longitudes, when not influenced by the

horizontal or directive power, which would be at the magnetic poles—and in all latitudes when the needle is turned east and west.*

96. The dip of the needle increases in proportion as the *mean temperature decreases*—and not in proportion to the increase of distance from the magnetic equator. A few facts will illustrate this position.

97. In 1818, Captain Sabine found the dip $83^{\circ} 08'$ on the ice in Davis' Strait, in latitude $68^{\circ} 22'$; but in 1819–20, he found the dip $83^{\circ} 4'$ in latitude $64^{\circ} 00'$, nearly four degrees farther south in the same strait—from which we infer, that the temperature of latitude $64^{\circ} 00'$ during 1819–20, was about the same as that of $68^{\circ} 22'$ in 1818. It is highly probable, that the mean annual temperature is nearly the same, viz., about zero, from latitude 68° or 69° to the northern extremity of the continent—and from Baffin's Bay, longitude $82^{\circ} 10'$, to longitude 112° or 115° west—and that the magnetic needle would be nearly vertical over the whole extent of that desolate region. Such is the result of all the observations which have been made within the last fifteen years. In longitude 25° W. and latitude 76° N., where the mean temperature is fifteen degrees higher, Captain Sabine found the dip only 80° . At Spitzbergen, nearly 80° N. latitude, he found the dip only $81^{\circ} 10'$ —while we have seen, that at Melville Island, in latitude $74^{\circ} 30'$, it was $88^{\circ} 43'$ —and probably two or three degrees farther south, it is 90° . It would be a waste of time to multiply examples in proof of a proposition so plain and

* It has been a matter of great astonishment to me, that no account has been given of this simple experiment, in any of the books on magnetism which I have consulted.

obvious. It is highly probable, that the magnetic poles, as well as the magnetic equator, shift a few degrees north and south, as the sun passes from one side of the equinoctial line to the other.

98. It may be asked, why the northern portion of our continent, where the Rocky Mountains terminate in the Arctic Sea, in latitude 70° N. and longitude 135° W., is not colder than Bear Lake, Melville Island, Winter Island, &c., being more elevated. We answer, because it is much nearer to the western coast of the continent, and because all western coasts are warmer than eastern coasts in the middle and higher latitudes, owing to the greater amount of condensation and precipitation, by which caloric is given out, as we before explained.* At the mouth of the Mackenzie, the Arctic Sea is quite open during summer—while farther east, from longitude 112° W. to Baffin's Bay, for seven hundred miles, the sea and inlets are never clear of ice. In latitude 70° N., the American continent extends from Icy Cape, longitude 165° W., to Davis' Strait, $82^{\circ} 30'$ W. longitude, two thousand miles in width—and if we include Greenland, with Baffin's Bay and Davis' Strait, which are nearly always covered with ice, we have a continent more than three thousand miles wide, and extending nearly half around the polar circle. This single fact solves the problem of our excessive winters—and explains why the magnetic needle obeys the American pole over two-thirds of the northern hemisphere.

99. The mean annual temperature of Labrador, in latitude 57° , is $26^{\circ} 42'$, the mean temperature of winter being about

* See Section 121, Part I.—and Sections 68 and 69, Part II.

zero, nearly on a level with the sea ; while at Enontikies in Iceland, latitude $68^{\circ} 30'$, and longitude $20^{\circ} 47'$, the mean annual temperature is about 26° , from which it is evident, that after leaving the continent, we must advance upwards of ten degrees of latitude northward to find the same temperature in a maritime or insular situation. At North Cape, in Lapland, latitude 71° , we find a higher temperature than at Labrador, in latitude 57° , the mean being 32° —hence we perceive, that the line of mean annual temperature is fourteen degrees higher on the northern coast of Lapland, than at Labrador, owing to the maritime character of its climate. The lines of equal dip of the needle, invariably follow the same laws which govern the isothermal lines.

100. Humboldt estimates the mean summer temperature of Cumberland House, in latitude $53^{\circ} 57'$, the same as that of Central Russia, in latitude $58^{\circ} 30'$, and longitude 36° east. In latitude 47° , at Quebec, the mean annual temperature is nearly as low as that of St. Petersburg, in latitude 60° . Such are the differences of temperature caused by the relative extent of land and sea.

101. A writer in the Edinburgh Philosophical Journal, commenting on the magnetic theory of M. Hansteen, asks, who has been able to explain the cold of Siberia, Greenland, or Terra del Fuego ? Who, the strange variations of the polar climate, or Cook's observations on the different distances to which the polar ice extends from the south pole, in the Pacific and Atlantic Oceans ? We trust that these questions have been satisfactorily answered in this essay ; and that future observations will establish our conclusions on the firm basis of positive demonstration.

102. A collection of very important facts in relation to the variation of the needle in the United States, has been recently published in the American Journal of Science, by General Schuyler, Mr. De Witt, Mr. George Gillet, and others, which conclusively demonstrate, that the American pole has shifted from east to west, and from west to east, within the last hundred and fifty years. Mr. Gillet gives the western variation at Philadelphia, on the authority of Mr. Scull, as $8^{\circ} 30'$ in 1701. In 1793, according to the observations of Mr. Brooks, it was $1^{\circ} 30'$, making a difference of seven degrees in ninety-two years. In 1794, the needle was observed to *recede westward*, according to the observations of Mr. Brooks and Mr. Humphreys at Philadelphia; and by others in Virginia.

103. About the year 1810, the late Mr. Spencer, of Litchfield County, published in the Connecticut Courant, that for a number of years then past, the needle had declined to the west. Mr. Nathaniel Goodwin, of Hartford, who has attended to the variation for several years past, states, that the needle has steadily tended to the west. Mr. Gillet states, from his own observations, that "since 1805, the needle has declined to the west more than a degree." It is impossible to reconcile the above observations with the hypothesis of a revolutionary movement of the American pole; while they are in perfect accordance with the irregular shifting of the pole, caused by unequal accumulations of ice in the Arctic circle at different periods, as we shall see hereafter. Dr. Bowditch gives the following results of observations made farther north.

104. "The variation of the magnetic needle, in the vicinity of Boston, has decreased since the first observations were made in this country, at the rate of a degree in thirty or forty

years; for by the papers published in the first volume of the Memoirs of the American Academy, it was $9^{\circ} 00'$ west, in the year 1708— $8^{\circ} 00'$ in the year 1742—and about 7° west in the year 1782." Within three or four years, it has been mentioned in several periodical publications, that the variation had ceased to decrease, and was then rapidly increasing. This was stated to be the case, particularly in New York by persons, who, from their official situations as public surveyors, were supposed to be most competent to judge of the subject; and observations were adduced to prove, that this change had taken place between the years 1804 and 1807. Thus, one of the boundary lines of Rensselaer Parish in Albany was found in the year 1800, N. $46^{\circ} 48'$ W., by compass; and in the year 1806, N. $46^{\circ} 12'$ W., the true bearing being N. $51^{\circ} 46'$ W. Whence it was inferred, that the variation had increased $36'$ during that period. In Herkimer, in New York, the variation was observed in the years 1800, 1804, and in 1807. In the first interval of four years, it had decreased $4'$, and in the last interval of three years, had increased $15'$. A turnpike road, which was laid out by compass in 1805, had varied in its bearing in 1807, $45'$, indicating that the variation had increased by that quantity. (*See Silliman's Journal, April, 1829.*)

105. From all these facts and observations, it is evident, that the American magnetic pole has an irregular, oscillatory motion from west to east, and from east to west, caused by unequal accumulations of ice in the polar regions. Professor Sewall has stated, in the Memoirs of the American Academy, that the needle varied $47'$ west in about two or three months, in the year 1782. Dr. Bowditch thinks, that

"the above differences of variation are not too great to be accounted for by the diurnal variation alone." There can be no doubt, that the annual, monthly, and diurnal variations are greater in the United States, than in England, owing to the greater variations of temperature. The diurnal variation of the needle in England, according to the observations of Canton, are 6 minutes 58 seconds at the winter solstice, and 13 minutes, 21 seconds at the summer solstice. In the United States, the daily variation of temperature is frequently 60°, while in England, it is rarely half so much.* Moreover, the annual range of temperature in the middle and northern portions of the United States, is from 100° to 140°, while in England, it is seldom more than 80°. According to observations made by Mr. Reuben Haynes, at Germantown, latitude 40° 3' near Philadelphia, the mean temperature was 49° 6', in 1821—52° 4', in 1822—50° 5', in 1823—and 54° 2', in 1825. During the years 1826 and 1827, at New York, it was about 54°; from all which it appears, that the mean annual temperature of different years varies several degrees—doubtless, owing to partial accumulations of ice in the northern seas, which are temporary in their duration.

106. According to tables of temperature taken from the annals of chemistry and physics, the extremes of temperature in central Europe, are from 5° of Farenheit in winter to 95° and 98° in summer. In the year 1795, the mercury fell to 10° below zero in France, but it was an extraordinary event, and perhaps may not occur again in a century. It is not very

* M. Hansteen fancifully observes, that "the variations of the magnetic needle, are a mute language revealing to us the changes perpetually going on in the interior of the earth." If he had said the changes of *temperature* perpetually taking place on the surface of the earth, we should have agreed with him.

often that the mercury falls below zero in the United States, south of latitude 43° N., except on elevated situations, so that we have presented the *extremes* of temperature rather than the general character of the climate.

107. Observations on the variation of the needle, as well as those on the temperature of different climates, must be continued for a considerable time, and the mean of the whole accurately calculated before they can be relied on. Unfortunately, the observations from which our magnetic charts are constructed, are not all of this character. There is nothing more wanted at the present time, than a series of well conducted experiments and observations on the variation, dip, and intensity of the needle in different parts of the world. The result of M. Hansteen's observations in the north of Europe and Asia, have been a valuable acquisition, as far as they go; but we are greatly in want of more extensive and precise information from other parts of the globe, especially in the southern hemisphere. We trust that Dr. Breda will supply this defect, during his voyage to the Antarctic circle, as far as possible.

108. We shall now endeavor to explain why the American centre of greatest cold has shifted several degrees from west to east within the last hundred and fifty years.

109. We have shown that the Greenland Sea was closed with ice from the fourteenth to the seventeenth century or longer—that it was probably obstructed in a similar way, nearly 2000 years ago, by which the northern ice was prevented from floating southward—therefore must have accumulated in, and covered the Arctic Sea and lowered its temperature. During such a state of the northern ice, the winds of the polar winter blew

over them, without receiving warmth as from a body of deep water—by which a change of climate was extended to the lower latitudes. If the climate of Europe were really colder during the greatness of Rome,* and from the fifteenth to the seventeenth century, than from the eighth to the fifteenth century, when the Greenland Sea was annually open, and *when the vine flourished in England*, the above causes must account for it.

110. During a long continued accumulation of ice around the northern coasts, the rivers would be perpetually frozen up in their beds, or accumulated in icy ramparts at their mouths. The valleys would be filled with snow and icebergs—and the whole surface of the northern interior would become a theatre of perpetual congelation, from Hudson's Bay to Melville Island. During such a state of things, the centre of greatest cold would be found near the longitude of Melville Island, which is near the northern centre of the continent. Accordingly, we find from observations made at the University of Cambridge, and recorded in Professor Silliman's Journal, volume XVI., that the magnetic pole was several degrees further west one hundred and fifty years ago, than at present, as the western variation of the needle was then $11^{\circ} 15'$ at Boston, and is now only about 6° west.† From Captain Parry's

* Greece, Turkey, Wallachia, Moldavia, and Hungary, where the vine and olive now flourish, are described by ancient writers, as having a climate similar to that of Russia and Sweden, in our times. In France, also, the rivers were frozen over much more frequently, and for longer periods, in the time of Cæsar's campaigns in Gaul, than at present.

† It is a remarkable fact, that during this period, the western variation was only $4^{\circ} 30'$ at London, whereas it is now about 24° , which clearly demonstrates, that the needle did not then obey either the American or Asiatic pole in the west of Europe, but some other intermediate point of magnetic attraction, which has since disappeared.

observations, the American pole is now about 102° west longitude, which is several degrees east of Melville Island. In all this we perceive nothing like a revolutionary movement of the "cold meridians," or magnetic poles, round the geographical poles. The truth is, that such a revolutionary movement is utterly impossible, for this plain reason, that all other things being equal, the greatest cold in the polar circles must always accompany the largest body of fixed surface. It is equally evident, that they cannot remain permanently stationary; but must shift in obedience to those laws which regulate the temporary accumulations and dissolutions of ice in the northern seas. In 1824, during his third voyage, Captain Parry found the icy barrier in Baffin's Bay one hundred and fifty miles broader, than when he passed it in 1819, proving that the accumulations of ice are greater during some years than others.

111. Posterity will wonder at the pertinacity of the British government in sending their brave and intrepid navigators repeatedly through Baffin's Bay, in quest of a north-west passage, after such clear demonstrations of its being near the coldest part of the northern hemisphere. Why did they not explore the north of Greenland by land, and ascertain how far it extends towards the pole? or why did they not make an effort to pass *round* Greenland and the northern continent? It is highly probable that they might have failed even then, as the great extent of continent at its northern extremity, acts as a perpetual barrier to the arctic ice, which would otherwise be floated southward during summer, and leave the northern sea open. The failure of Captain Parry in his attempt to approach the pole on the ice, from Spitzbergen,

in 1827, furnishes no argument against the possibility of navigating the Arctic sea beyond the continent, if undertaken at the proper time. On the contrary, he states that the general movement of the ice southward, carried them back faster than they were able to advance northward, which proves that the ice does break up during summer. He moreover states, that the temperature was milder, and that more rain fell north of Spitzbergen, while they were on the ice, than they had encountered during the seven summers which they spent in the Arctic regions.*

112. We have seen that the strongest magnetic pole of the northern hemisphere, is not far from latitude 72° north, longitude 102° west, on the American continent—and that the weaker north pole is on the Asiatic continent. Hansteen placed it in latitude 85° 12' north, and longitude 140° 6' east from Greenwich, in the year 1820. We before stated, that a strong probability existed of there being *two poles* in the north of Asia. The truth is, our information is very imperfect in relation to the exact position of the magnetic poles—and still more so, in relation to the lines of no variation. Future and more accurate observations are greatly wanted.

* We are strongly inclined to believe, with an intelligent writer in the American Quarterly Review, vol. vi., that "the north-west passage should be attempted by passing round Icy Cape, and sailing eastward, with the west wind, through the polar sea." We have no doubt, that the passage might be effected in that way, if undertaken in July or August, after the ice in the Arctic Sea is broken up and dissolved, as there is known to be a constant current from west to east, north of the continent. Will this government neglect the opportunity of sending an expedition suitably equipped, for the purpose of achieving this long desired object? Or will it choose rather to suffer our naval vessels to rot in our dock yards, and our officers to remain unemployed? If so, we shall despair of republics doing any thing towards the advancement of science.

113. The strongest pole* of the southern hemisphere, according to Professor Hansteen, is situated in south latitude $68^{\circ} 52'$, and $132^{\circ} 35'$ east, from the meridian of Greenwich, southwest of Van Diemen's Land ; and the weakest pole of the same hemisphere, is situated to the south-west of Terra del Fuego, in latitude $78^{\circ} 16'$, and longitude $135^{\circ} 59'$ west from Greenwich. That there is a body of land in that region is proved by the fact which is stated by Captain Fanning, that toward the pole, there are soundings in from fifty to one hundred fathoms of water, between latitudes 66° and 69° , and in longitude 140° west. M. Hansteen supposes, that "these four poles revolve around the geographical poles in unequal periods from west to east—that the American magnetic pole will perform its circuit round the north pole in 860 years, and the Asiatic pole in 1760 years—that the strongest pole in the southern hemisphere accomplishes its revolution round the south pole in 4609 years; and the weaker one in 1304 years."

114. We shall add but little to what we have already said on this hypothesis. It appears to have no other foundation whatever, than the shifting of the magnetic poles a few degrees from west to east, within the last two hundred years. Had the movements of the poles been uniform in given periods of time, there would be some ground for supposing a periodic revolutionary progress round the poles of the earth's axis. But we know, from the best authenticated observations, that their movements are irregular, and even retrograde—that the

* It is highly probable, if not demonstrable, as we shall see presently, that the strongest magnetic pole in the southern hemisphere, is situated about *midway* between the poles south of Terra del Fuego, and of Van Diemen's Land—and that the needle obeys it over more than two hundred degrees of longitude.

pole south of Van Diemen's Land has been nearly stationary for the last one hundred and fifty years—while the North American pole has been nearly stationary for the last forty-five years, but with a slight retrograde motion within the last thirty years. We also know, that they are perceptibly influenced by the annual, monthly, and diurnal changes of temperature—from which we infer, that all the complicated phenomena of magnetic polarity, are resolvable into the operation of those laws which regulate the distribution of temperature throughout the globe; and not to “the revolutionary movements of imaginary axes in the interior of the earth.”

115. In addition to the facts which we have already advanced, to prove the connection of magnetic polarity with the unequal distribution of temperature in the tropical and polar latitudes, we find from the observations of Professor Hansteen, that the maximum intensity of the magnetic force, prevails during winter*—when the difference between the temperature of the tropical and polar latitudes is greatly increased—and that the minimum intensity of magnetic attraction occurs during summer. This is readily understood when we reflect, that the mean temperature is always the same at the magnetic equator, while it is from sixty to eighty-five degrees lower at the American magnetic pole during the long winter night, than during the long summer day. M. Hansteen also found, that the dip was about fifteen minutes greater during summer, than during winter, which must be owing to a diminution of horizontal intensity during summer. He also found, that the dip was from four to five minutes greater in the fore-

* M. Kuppfer, of St. Petersburg, has recently verified Hansteen's observations on the difference between the dip and intensity during summer and winter.

noon than in the afternoon, which is also owing to the diminished horizontal intensity while the sun is on the magnetic meridian. M. Hansteen and Mr. Christie have *proved* by numerous observations, that the magnetic intensity has a *daily variation*, the minimum occurring between ten and eleven o'clock in the forenoon, and the maximum between four and five in the afternoon.* Hansteen found the greatest daily variation least in winter, and greatest in summer.

116. An effort was made in the year 1804, at the desire of the French government, by Guy Lussac and M. Biot, to ascertain whether the magnetic force experiences any perceptible diminution at considerable elevations above the surface of the earth. For this purpose they ascended together in a balloon to the height of 13,124 feet, where they discovered no appreciable difference. They state, however, that they found it impossible to keep their balloon steady, which to a considerable extent, neutralizes the value of their experiments; especially as other observers, equally accurate, have arrived at different conclusions, under more favorable circumstances. M. Kuppfer found a considerable diminution of magnetic intensity on ascending mount Elbrouz in the Caucasus, in the course of a journey undertaken by order of the emperor of Russia, in 1829; and that "the decrease was much more considerable than is conformable with the commonly received hypothesis of a focus of magnetic power situated at the centre of the globe." M. De Saussure had previously inferred, from some experiments which he made on the Col du Geant, near Mont Blanc, at the height of 11,270 feet, that "the magnetic force of the earth was reduced to four-fifths of what it was in the plains below." (See *Lib. of Useful Knowledge*, No.

* See M. Hansteen's observations in Appendix.

107, part III.—Art. Mag.) If the unequal distribution of caloric in the lower and higher latitudes be the cause of magnetic polarity, there must be a diminution of intensity as we ascend from the surface, because there is less difference of temperature between the *upper* regions of the atmosphere in the tropical and polar latitudes, than at the earth's surface on a level with the sea.

117. Professor Hansteen found a striking variation of intensity on ascending and descending the Round Tower in Copenhagen, which is one hundred and twenty-six feet high, with a walk of seven turnings which leads to the top. After several experiments below, which showed, that seven hundred and eighty-seven seconds of time were required to make three hundred oscillations, he returned to the tower, and found in the highest part of it, that three hundred oscillations required

842".37

One turning below required 836.57

Two turnings lower, 837.30

One and a half turnings lower, 834.43

Two turnings lower, 804.07

Down below within doors, 813.00

(See *Edinburgh Philosophical Journal*, vol. 4, p. 299.)

118. We have perceived, that the intensity, variation, and dip of the magnetic needle are governed by *periodic* changes of temperature. The *irregular* disturbances of the needle are caused by thunder-storms, great falls of snow, violent winds, volcanic eruptions, and the aurora borealis; all of which phenomena are immediately connected with the agency of caloric.

119. The variation of the needle increases as we advance

from the magnetic equator to the poles, in proportion as the distance diminishes—*viz.*, the difference between the angles of variation in the lower and higher latitudes, is proportional to the different lengths of the angles. Accordingly we find that at St. Thomas, which is near the magnetic equator, the variation is about 19° west, while at London, which is near the same meridian, the variation is 24° west, and at Iceland it is 40° west. At the latitude of Good Hope in Greenland, it is 51° west, and at the latitude of the magnetic pole, it is 90° west, making a right angle, and pointing due west. If we go north of the magnetic pole, it points to the south—if to the west of it, it points east—varying between all the intermediate points. In 1778, the variation was found by Captain Cook to be $19^{\circ} 51'$ east, at Nootka Sound, and $35^{\circ} 37'$ east, at Behring's straits. At the mouth of the Mackenzie River, in latitude $69^{\circ} 29'$, longitude $135^{\circ} 41'$, Captain Franklin found the variation $51^{\circ} 42'$.

120. It would seem that in the north of Europe, the needle is influenced by some intermediate point of attraction between the American and Asiatic poles, as it varies only 8° west at St. Petersburg which is 30° east from Greenwich. At Stockholm, 18° east longitude, the variation is $15^{\circ} 30'$ west. At Christiana in Norway, in longitude $10^{\circ} 30'$ east, it is 20° west. At North Cape, in Lapland, in longitude about 25° east, the variation is 6° west. In high latitudes, near the magnetic pole, the daily variation is much greater than in lower latitudes. At Port Bowen, Captain Parry and Lieutenant Foster found it from three to five degrees, and even as high as seven degrees.

121. The most mysterious circumstance connected with

magnetic variation is, that on many parts of the globe there is no variation of the compass. For example, there is no variation at Cape Hatterass, latitude $35^{\circ} 15'$ north, longitude 75° west from Greenwich ; and at several other points in the United States. At Pekin and Canton in China, and in many other parts of Asia, the needle points nearly due north ; also at Archangel in the north of Europe. In the southern hemisphere, the needle points to the south pole of the earth's axis at the eastern extremity of Borneo, and in the longitudinal centre of New Holland. According to Hansteen's Chart, there is no variation in the Pacific Ocean in latitude 20° south, and longitude 120° west. But as we before stated; the observations on which our charts are constructed are too few and imperfect to enable us to present a precise account of magnetic variation in the southern hemisphere.

122. The reason why the needle points to the geographical poles, and not to the magnetic poles at the above places, has never yet been explained ; nor are we prepared to assign any other cause, than that *between the points where there is no variation and the true poles, there must be minor centres of attraction*, which influence the needle more strongly than do the magnetic poles, which are farther off. This influence is obvious in the north of Europe, where the western variation is much less than in England and France on the same meridians ; which must be owing to the influence of Greenland and Spitzbergen, which are situated between the meridians of St. Petersburg and the American magnetic pole. Perhaps the needle may be also influenced by the centres of cold, in the north of Europe and Asia. It is evident that the needle is affected by intermediate centres of attraction between the tropics

and the polar circles from the fact, that there is a diurnal variation during winter, while the polar circles are entirely excluded from the sun's influence, which proves, that the daily variation must be owing to the successive heating and cooling of the magnetic meridians in *lower latitudes*, caused by the daily revolutions of the earth on its axis. The greater daily variation during summer than winter, is probably owing to the sun's sweeping daily round the pole in such a manner as to cause a successive exposure of different meridians of the polar circle to his influence—while in winter, his daily heating influence is limited to lower latitudes.

123. A few degrees west of the meridian of London in the southern hemisphere, there is no variation, which is evidently owing to a large body of land in the direction of the true south pole. Captain Morrell, who has made important discoveries in the southern hemisphere, informs me that he coasted a continent or large body of land 47° —beginning west longitude $47^{\circ} 21'$, latitude $67^{\circ} 52' S.$, which he thinks extends westward as far as 120° or 130° west longitude.

124. Judging from the direction of the needle, we are inclined to believe that this continent extends south-east also, perhaps as far as the eastern magnetic pole.* How far it extends towards the south pole, it is impossible to say; but reasoning from analogy, and from the excessive coldness of New South Greenland as described by Captain Morrell, it is not improbable that it extends to near the south pole in the direction of the true meridian from England. Captain Morrell states, that

* We have just seen in the New York Commercial Advertiser, an extract from an English newspaper, stating, that a certain British whaler had recently discovered land in the South Seas, extending from longitude east $47^{\circ} 30'$ to longitude $69^{\circ} 29' W.$, in high southern latitudes.

beyond latitude 60° there is no soil or vegetation on New South Greenland; but a succession of vast mountains, or columns of impenetrable rocks, ice, and snow: from which we infer that it is even colder than Melville Island, as Captain Parry⁷ found there a few species of stinted vegetation.

125. Captain Morrell thinks, that New South Greenland is quite as cold in latitude 60° , as North America in latitude 70° ; and that the mean temperature of the Southern ocean, in latitude 50° , is about equal to that of latitude 40° on the North American continent: but as he did not winter on New South Greenland, nor remain any length of time at one place, he could give no thermometric tables.

126. We had inferred the existence of a *third centre of magnetic attraction* of great power situated not far from the true south pole, from the direction of the needle, which points due south, a few degrees west of the Cape of Good Hope—and from the great number of enormous icebergs frequently met with, south-west of the Cape, which are known to be formed among mountain valleys, and not in the sea; from which we concluded that there must be a large body of land towards the south pole where these icebergs were formed, and a centre of cold proportional to its extent and elevation. Since completing this essay, we met with Captain Morrell, who confirmed our hypothesis previously founded on analogy, by stating that he had coasted a new continent 47° of longitude.

127. We have seen that the needle is not directed by the pole of the earth in the northern hemisphere, but by the centres of greatest cold, and that these centres of maximum cold are caused by large bodies of land in high latitudes, where icebergs are formed, from which they descend into the sea, and are

carried by the polar currents to lower latitudes. We hesitate not to assert, that there never was, and never will be a centre of magnetic attraction, situated over a large expanse of water, far from land.

128. Should there be a continuous body of land from the eastern south pole, to the Terra del Fuego pole, it is more than 4000 miles long, and if it extends far towards the true pole, it must be greatly colder than arctic America. That there is a large body of land in the direction of the strongest south pole ; and also in the regions of the weaker magnetic poles, we have no doubt. This land may be divided by Bays or Straits, of greater or less extent ; and it may extend farther south in the neighborhood of the magnetic poles, than in other portions of the antarctic circle. From the extreme coldness of New South Greenland, we venture to predict, that ships will not approach very near the south pole.

129. It is highly probable, that M. Hansteen has placed the Asiatic pole several degrees too far north, as we have numerous accounts from the Greenland whalers of a heavy swell from the north east of Spitzbergen, proving, that the sea is open in that direction : and because persons who have passed the winter at Kola in Lapland relate, that during the severest weather, whenever a northerly wind blows, the cold diminishes instantly, and that if it continues, it always brings on a thaw as long as it lasts. When Captain Parry wintered at Melville Island, he discovered the same effect, but in a less degree.

130. Barrington says, "it is the invariable tradition of the Samoides and Tartars, who live beyond the Waygat, that the sea is open to the north of Nova Zembla all the year ; and that the most knowing people of Russia are of the same opinion."

From all these circumstances taken together, and from the fact that the exact position of the Asiatic pole has never been ascertained by finding where the dipping needle would become vertical, we are disposed to believe that it is not so far north as eighty-five degrees. It is much to be regreted, that we have not at present a sufficient number of accurate observations, on the temperature of northern Asia and Europe, to determine positively whether there be two centres of cold on the eastern continent. The accumulation of ice around the continent, and at the mouths of its great rivers, must greatly influence their position, at different periods.* The absence of a swell from the north-west of Spitzbergen may be owing to the intermediate position of Greenland; or to the prevalence of ice in the Arctic Sea, north of the American continent, which is doubtless often the case.

131. The pointing of the needle to the true north pole at Cape Hatterass, may be owing in part to the coldness of the Appalachian mountains, which trend somewhat toward the north pole, and which may deflect the needle from the direction of the magnetic pole, to that of the true north pole. The lofty mountains of the eastern continent—from the Himalayas of the south, to the Stavonoys of the north-east, and the Urals stretching north between Europe and Asia—also, the cold elevated table lands of central Asia, must produce what Dr. Brewster terms “cold meridians,” or centres of cold, which deflect the needle from the distant magnetic pole, and direct it towards other points. Accordingly, we find the variation lines in Asia, very crooked and complicated.

132. So feeble is the directive power of the needle near the

* See tables of magnetic variation in the Appendix.

magnetic pole, that in Regent's Inlet, Captain Parry found it overcome by the attraction of the ship's iron.* Captain Scoresby has estimated the force of local attraction caused by the ship's iron, at about one-eleventh of the directive power in England—in Greenland where the compass traverses well, he found the number of oscillations of a horizontal needle, fewer in a given time than in England. He also thought that in a low temperature, the vibrations performed by the needle before it stopped were fewer. Captain Ross concluded from his experiments on local attraction, that the deviation appeared to be materially affected by heat and cold, as well as by atmospheric humidity and density; and that the direction of the wind seemed to have an irregular effect on the deviation.

133. Captain Scoresby says, that the greatest deflection of the needle from the magnetic meridian, occurs when the ship's course is east and west; because the focus of attraction then operates at right angles to the position of the compass needle; but the anomaly generally disappears when the course is about north or south, because the focus of attraction is then in a line with, or parallel to the compass needle, and consequently has no power to deflect it from its direct position. (*See Arctic Regions, Vol. II., p. 548.*) The extraordinary variation of Captain Parry's compasses, in latitude 68° , off Igloolik, must have been caused by local attraction of the ship's iron, overcoming the directive power, while the ship's head was east. Captain Scoresby occasionally carried a compass in the crow's nest, fixed at the mast-head, "where it was found to be free from the anomalies which are so sensible in a compass on deck." (*See Arctic Regions, p. 549.*) Captain Scoresby has given

* See Sections 92 and 95, Part II.

numerous examples of shipwreck, caused by the deviation of the needle in ships loaded with iron, steel, &c.

134. It has been an established article of belief among all writers on magnetism, that the needle is influenced simultaneously by the poles of both hemispheres. For example, that the south end of a compass needle placed on any point of North America, obeys the pole south west of Terra del Fuego, while the north end is directed by the North American pole. We have seen that the South American pole is more than 30° west of the North American pole, from which it is evident, that the needle cannot obey both poles at the same time at New York, London, Paris, &c., because if it did, it could never point to either pole, but would assume an oblique direction. There is another fact which is decisive on this point. At London (in the northern hemisphere) the variation is 24° west, while on the same meridian in the southern hemisphere, the needle varies only two or three degrees from the true meridian, which is proof positive, that the needle does not obey the north and south poles simultaneously. It is probable that at the magnetic equator, it is influenced by both, though unequally, according to their relative power.*

135. I have no doubt, that for 100° east, and nearly 120° west of the meridian of Greenwich in the southern hemisphere, the needle obeys a third centre of magnetic attraction, as before suggested, which is situated not far from the meridian of London, and *which has never before been suspected to exist*. We can readily understand why the variation is so small on

* The directive power or intensity of the needle must be in proportion to the amount of *free*, or *radiant caloric*, which passes from the tropical to the polar regions; which, probably, acts upon it in a mode somewhat similar to that of an atmospheric current, on the vanes of our church steeples.

the meridian of London in the southern hemisphere, if there be a centre of magnetic attraction in the direction of that meridian. Until the above facts are understood and recognized, our magnetic charts will continue, as they have heretofore been, only stumbling blocks, to those who engage in magnetic inquiries. Without a great deal of patient and independent research, we should have been discouraged on our first examination of Dr. Halley's chart, corrected and improved by Mountaine and Dodson. It was a perfect enigma, which never could have been solved without a recurrence to first principles. By the way, it is not those who perform the greatest number of experiments, or collect the greatest number of facts and observations who do most to advance knowledge ; but those who reduce a chaos of undigested phenomena to order—point out their relations—and deduce from them general principles for the direction of other experimenters. *Indeed*, there is nothing more fallacious than experiments, when not guided by general principles.

136. We have seen that there is no necessity for resorting to a central magnet extending through the earth's axis, nor to accumulations of iron at the poles, to account for magnetic polarity. Every thing in nature is more or less magnetic. When any two substances are brought near to each other, if differently electrified, they attract each other. When two pith balls are differently electrified, they become magnetic. When glass or amber is rubbed, they become magnetic, attracting light bodies to them.* From the few experiments we have made, we believe that every solid substance in nature may be

* The same is true of the metals, if insulated when rubbed.

rendered magnetic by friction, which develops caloric. In fine, we believe that the earth is magnetized by solar heat, and that all the diversified phenomena of magnetic attraction are resolvable into the subtle, silent agency of caloric in some of its forms.

137. From numerous experiments of Caulomb, Hansteen, Scoresby, Harris, and many other philosophers of Europe, we learn that almost every species of solid substance, mineral and vegetable, in a greater or less degree is susceptible of magnetism. Caulomb proved this by placing needles formed of wood, bone, glass, and many other substances, between steel magnets, of opposite polarities, "when they arranged themselves in the direction of the magnetic meridian, and if disturbed from their position, they always returned to it with oscillations." (*See Library of Useful Knowledge, on Magnetism.*) Captain Scoresby ascertained, that a few blows with a hammer, rendered steel magnetic, when held in the direction of the dipping needle, and that magnets could be made at any time in that way. In addition to which, we have ascertained by repeated experiments, that iron and steel may be rendered strongly magnetic by friction between two plates of unmagnetized iron or steel, without any reference to the position in which they may be placed—and that the various species of metal, wood, sealing wax, glass, and even paper, will assume a polar direction, if placed on water, after being warmed by friction. An important fact connected with this part of the subject is, that in the polar regions, compass needles lose their magnetism much sooner than in the lower and warmer latitudes, as was observed by Captain Parry and Lieutenant Foster.

138. It is highly probable, that nearly all articles manufac-

tured from steel and iron are rendered more or less magnetic by the friction which they undergo while forming and polishing. Mr. Varley examined many dozen balances of time pieces, out of which he could not find one that had not polarity." (See *Edinburgh Philosophical Journal*, Vol. IX., p. 50.) I placed a dozen fine sewing needles on water in succession, all of which polarized, but some more speedily than others. When rubbed between two metals, until warm to the touch, they traversed briskly, and settled very soon in the direction of the magnetic meridian. Soon after communicating our views of the connection between caloric and magnetism to a gentleman of this city, he submitted the blade of his penknife to friction on the face of a smoothing iron, with a common poker—when it became *strongly magnetic*. We have performed the experiment in various ways, and always with the same result. Great irregularities in the time of chronometers have often resulted from the balance wheel becoming magnetic. Captain Scoresby has suggested a mode of rectifying the errors of chronometers by suspending them in such a way that they will always keep in the same position at sea, with respect to the magnetic meridian. (See *Edinburgh Philosophical Journal*, Vol. IX., p. 54.)

139. The production of magnetism in steel and iron by electricity, was known to our countryman, Dr. Franklin, and to the celebrated Beccaria, more than fifty years ago; but was first demonstrated by a series of well conducted experiments by Dr. Oerstedt of Copenhagen, in 1819. Professor Moll of Utrecht, M. De la Rive of Geneva, M. Arago of Paris, Dr. Wollaston, Sir Humphrey Davy, Mr. Farraday, Mr. Herschell, Mr. Christie, and many other philosophers of Europe,

have repeated and extended the experiments of Oerstedt, until electro-magnetism has assumed the character of a separate department of physical science. It cannot be said, however, that it has yet been reduced to a system of principles, or that its relations to terrestrial magnetism have been satisfactorily pointed out.

140. We shall present only a brief outline of the most important results obtained by different experimenters. We would observe at the same time, that the limited scale on which most of these experiments are performed, render them less satisfactory than a general survey of the operations of nature throughout the globe, where the leading facts are exhibited on a scale of comprehensive grandeur and certainty, which cannot fail to arrest the attention of every enlightened mind. For example, we are told by seamen, that on approaching icebergs, the compass needle is frequently disturbed, as it is by all sudden and great changes of atmospheric temperature. We consider observations of this nature more decisive than a hundred experiments made by ranging a few small pieces of ice around the needle, and noting their effect upon it; because all such experiments must be partial, and modified by the general magnetic influence of the earth. What the precise *mode* may be by which caloric renders metals magnetic, we are not prepared to say*—nor is it of any more importance, than that we should know precisely *how* the vital principle is united with ponderable matter. We know the general fact, that if iron or steel be made red hot, and suddenly cooled in

* Mr. Abraham of Litchfield, supposed, from a series of experiments, which he performed, that magnetizing a steel needle, rendered it a better conductor of electricity than in its ordinary state. (See Dr. Green's Work on Electro-Magnetism, p. 104.)

water, they become magnetic. We also know, that lightning renders articles of every description manufactured from iron and steel magnetic—and that it has often depolarized compass needles, both on land and at sea.

141. But the most astonishing experiments ever exhibited to the world, proving the agency of galvanic heat in the production of magnetism, are those performed by Professor Henry, and Dr. Ten Eyck of Albany, in 1831. They constructed a horse shoe magnet of Swedish iron, weighing sixty-nine and a half pounds, with an armature weighing twenty-three pounds. Around this magnet they wound twenty-six strands of copper bell wire, each thirty-one feet long, and covered with cotton thread. About eighteen inches of the ends of the wire were left projecting, so that the aggregate length of the coils was seven hundred and twenty-eight feet. On connecting the wires with a battery of $4\frac{7}{9}$ ths square feet, the magnet supported 2063 pounds. In one experiment with a smaller battery, the armature continued to support more than one hundred and fifty pounds, three days after the battery had been excited.

142. Professor Henry observes, that "several small wires conduct more common electricity from the machine than one large wire of equal sectional area; and that the same is probably the case, though in a less degree, in galvanism." Hence the advantage of multiplying the strands of wire in order to increase the power of the magnet. With a single pair of concentric copper cylinders, with zinc between them, the whole amount of zinc surface exposed to the acid being two-fifths of a square foot, and requiring only half a pint of diluted acid for its submersion, caused a horse shoe magnet

weighing twenty-one pounds, and wrapped round with nine strands of copper bell wire, each sixty feet long, to lift six hundred and fifty pounds.

143. We consider the attraction of two smooth plates of lead for each other, after being rubbed, of the same description. They adhere with equal force under an exhausted receiver, as under the pressure of the atmosphere: therefore must be held together by some imponderable intermedium—and as we know that caloric is developed by friction, and actually does exist between the plates, we infer that it causes their attractive force.

144. It is stated by Dr. Green, that the heat of the hand will produce a sensible declination in a delicately suspended needle—and that Lieutenant Johnson, of the British navy, observed a considerable variation of the compass needle, by simply wiping the dust from the glass cover with a silk handkerchief or other soft substance—also, that the rays of the sun in their passage through the glass alter its electrical state, and cause it to affect the needle. (*See a late work on Electro-Magnetism, by Jacob Green, M.D., Professor of Chemistry, in Jefferson College.*) From the above facts and observations, it is obvious that compass needles should be placed in boxes of wood, or some other imperfect conductor of heat, as recommended by Mr. Fox. The needle should not be too light, and the cylindrical form least exposes it to being disturbed by currents of air. When great accuracy is required, these precautions are indispensable, and the glass covers should be double. Dr. Yelin inferred from his thermo-magnetic experiments, “that all metallic bodies acquire magnetic properties, when their various parts are unequally heated, and

that the action is stronger as the difference of temperature is greater." (*Bib. Univers. XXIV.*)

145. Whenever an oblong metal is brought near to a prime conductor, it becomes electrified positively at one end, and negatively at the other end. If the positive end of a wire thus electrified, be brought near to the negative end of a similar wire, they attract each other—but if either the positive or negative ends be brought together, they repel each other. The same law applies to magnets—poles of the same character repel, while opposite poles attract each other. When, however the north pole of a *large* magnet is brought near to the north pole of a *small* magnet, they attract each other—an exception to the general law, which I ascertained by repeated trials, and which I have not seen noticed by writers on magnetism.

146. It has been demonstrated mathematically, by *Æpinus* and *Caulomb*, that the attraction and repulsion of electricity and magnetism, like that of gravitation, operate inversely, as the squares of the distance—and Mr. Harris has proved, "that every substance susceptible of magnetism by induction, interposed as a screen, tends to arrest the action exerted by a magnet on a third substance." He determined that this interceptive influence is as the mass of intervening substance, and inversely, as its susceptibility of receiving induced magnetism. He inferred from various experiments with different substances, that this interceptive property is common to all matter, though possessed in various degrees, by different kinds of substances, and that in order to render it sensible, it is only requisite to employ them in masses proportionate to their respective magnetic susceptibilities." (*Lib. of Useful Knowledge—Article, Magnetism.*) It is well known, that a thin

coating of wax, which is a bad conductor of electricity, greatly diminishes the power of a magnet ; and Dr. Pascalis informs me, that the cocoons of the silk worm, totally intercept the magnetic influence.

147. When a metal or other substance, becomes saturated with electro-magnetism, further induction is prevented by the repulsion of the electric particles, which seek to expand themselves—and thus impart electric currents to other substances less electric, rendering them also magnetic. M. Arago, showed in 1824, “that if a plate of copper, or of any other substance, be placed immediately under a magnetic needle, it exerts sufficient influence upon its movements, to diminish sensibly the extent of its oscillations. The needle is brought to rest in a shorter time than happens when no such substances are placed under it.” He further ascertained, “that when a circular plate of copper is made to revolve with a certain velocity, under a magnetic needle, supported on its centre, and contained in a vessel closed on all sides, the needle is found to deviate from its natural position in the magnetic meridian ; and the deviation is greater in proportion as the rotation of the plate is more rapid. If the rapidity of revolution be sufficiently great, the needle will be brought to revolve also, and always in the same direction in which the plate is made to revolve.” (*See Library of Useful Knowledge, on Magnetism.*)

148. M. Ampère, who has devoted much attention to the science of magnetism, refers it entirely to electricity ; but he explains all the phenomena of magnetism by “the action of electrical currents, moving at right angles to the magnetic meridians.”

149. Experiments have been recently made in Italy, by two distinguished philosophers, M. M. Nobili, and Antinori, which exhibit more strikingly, the dependence of magnetism on electricity, than any preceding experiments in electro-magnetism, and by which the electric spark was drawn from the natural or permanent magnet. They have been repeated in England with some modifications, by Faraday, Saxton, Ritchie and Forbes,—and in the United States, by Professors Emmet and Silliman. M. Hachette, announced to the French Academy of Sciences, on the third of September, 1832, that Pixii had constructed an electro-magnetic apparatus which produced sparks at the distance of several mille-metres. It is well known, that natural magnets *retain* their power for indefinite periods of time, without much diminution—from which we are authorized to conclude, that they are constantly receiving a supply of electricity from the earth and the atmosphere, by induction.

150. We have just learned that Professor Botto of Turin, has repeated and extended these experiments—and that he “obtained from a horse-shoe magnet, surrounded in the middle with an electro-magnetic spiral, not only shocks, but a current of electricity sufficient to decompose water, acetate of lead, and other saline solutions.” (*See American Journal of Science, April, 1833.*) We must refer the reader for the particulars of these experiments, and for further information on electro-magnetism in general, to the various scientific journals of the day.

151. Mr. Boyle ascertained long ago, that if amber be exposed to the sun’s rays, it attracts light bodies; and Colonel Gibbs, an intelligent mineralogist of this state, has communi-

cated through the American Journal of Science, the important discovery, that when magnetic iron ore is first obtained from the earth at considerable depths; it is much less magnetic than after being exposed some time to the sun and air ; from which he infers, " that the sun is the source of magnetism." The opinion of Colonel Gibbs is strongly corroborated by the experiments of M. Barlocchi and M. Zantesdeschi. Professor Barlocchi found that an armed natural loadstone, which would carry one and a half Roman pounds, had its power nearly doubled by twenty-four hours exposure to the strong light of the sun. M. Zantesdeschi found that an artificial horse-shoe loadstone, which carried thirteen and a half ounces, carried three and a half more by three days exposure, and at last supported thirty-one ounces by continuing it in the sun's light. (See *Bache's American edition of Dr., now Sir David Brewster's Treatise on Optics.*) The truth is, that many distinguished philosophers have been verging towards this opinion for sometime past—and had they pursued the subject more at large, uninfluenced by pre-existing theories, they would probably have embraced it fully.

152. Professor Moll asks the question, " is there not some analogy between the sun's rays, and that force which so strongly effects the magnetic needle ?" Dr. Brewster notices the coincidence of the isothermal lines with the lines of equal dip, and of the points of maximum cold with the centres of magnetic attraction ; but maintains that they have a revolutionary movement round the poles of the earth—by which he has involved the whole subject in hypothetical speculation. (See *Edinburgh Encyclopedia, Article, Polar Regions.*)

153. Professor Hansteen also supposed, that terrestrial magnetism was in some way connected with solar and lunar influence ; but lost himself in a maze of speculation in regard to the manner in which the sun was magnetized—whether by a central sun—and whether the magnetic power was exerted in a general direction throughout the universe ; having the milky way for its equator, &c. It has been our object to trace its operations as exhibited on our own planet, and to show that it is owing to the agency of causes perpetually before our eyes.

154. Embracing, as M. Hansteen has done, the Halleyan hypothesis of two magnetic axes in the interior of the earth, and of their revolutions round the geographical poles, without offering any satisfactory proofs of their existence, it may be said that his *theoretical* views have shed but little light on this difficult problem.

155. M. Hansteen says, “as to the origin of those magnetic axes, we may suppose them to have been created along with the earth itself, or at a later epoch.” How unsatisfactory are the results of hypotheses ! Dr. Brewster thinks, that beyond the mere elements, the whole science of magnetism is still involved in obscurity. (*Edinburgh Phil. Journal.*)

156. It is impossible to conceive how the sun could magnetize the interior of the earth, while its influence reaches but a short distance below the surface ; so that this hypothesis is obviously inconsistent. The facts, however, which M. Hansteen has collected with so much labor and perseverance, entitle him to the gratitude of all the lovers of science.

157. The absurdity of supposing a revolutionary move-

ment of the magnetic poles, must appear obvious, when we learn, that according to M. Hansteen's theory, the American pole must have been about Behring's Straits two centuries ago; and that four centuries ago, it must have been in the north Pacific, or east of Asia.

158. If we admit the hypothesis of Halley and Hansteen, that there are two magnetic poles in the interior of the earth in each hemisphere, which revolve in unequal periods of time, will it explain the phenomena of irregular and retrograde shifting of the centres of magnetic attraction? Or the annual, monthly, and diurnal variations of the needle? Or does it afford any explanation of the *mode* by which these interior poles affect the needle? It is acknowledged, that distant objects cannot act upon each other, without some intervening medium. We have shown that such a medium does exist—that caloric in different forms, is abundantly distributed throughout nature—that it passes through the most ponderable bodies with great facility, from where it is plus to where it is minus—and finally, that it is probably the cause of all the motions and changing phenomena of matter.

159. Philosophers have strangely confounded the gravity of matter with its *inertia*. There is no such thing as perfect quiescence or inertia of matter. If we could conceive such a thing as the entire annihilation of caloric, we might also conceive of a total inertia of matter. The mind becomes bewildered in contemplating the reign of eternal darkness and repose, which would follow the universal extinction of caloric; unless it pleased the Almighty to create it anew.

160. I trust, that the numerous facts and analogies by which I have arrived at the foregoing generalizations, will exempt me

from the imputation of rashness, or of a wish to indulge in hypothetical speculations. I have endeavored as far as possible to confine myself to the inductive method, while the complicated character of the subject, and the recondite nature of the phenomena involved in its discussion, have presented many obstacles to its perfect elucidation.

161. If I have been so fortunate as to shed any new light on this important problem, I shall esteem it as the gift of Heaven, for it came to me unsought and unexpected, while pursuing another inquiry, without the slightest conception of the great truths to which it gradually led the way. I had no higher object than to ascertain the cause of unequal climates in different parts of the globe, and especially the cause of unequal winters in our own climate; with an ulterior view of obtaining some knowledge of the cause of epidemics.

162. The results have afforded me the more satisfaction, as they were obtained before I examined a single theory in relation to magnetism. Indeed, it is highly probable, that if I had commenced the study of magnetism, by a perusal of the various systems, I should have been bewildered in the labyrinth of contradictory facts and opinions which they contain.

163. The truth is, that we must revert to first principles, and study nature, or we shall never succeed in our efforts to extend the boundaries of truth. Are we forbidden to look beyond the horizon of our predecessors? What then is to be the progress of science in future times? Are we to surrender the glorious privilege of free and independent inquiry for the soul-paralyzing slavery of authority? If so, farewell all those pleasing hopes of human improvement which have been so

idently cherished by the loftiest and purest spirits of our race.

164. Should ignorance and malevolence assail me with abuse, and misrepresent the character and tendency of my labors, I shall regard them only so far as they may be calculated to diminish their usefulness—for I hold every other consideration subordinate to the great business of benefiting mankind—and that there is no power on earth which can deprive me the consolation which flows from a sincere desire to promote the cause of truth.

165. We have conveyed our views in the most plain and simple language, that every man of sense throughout the great republic of science, may judge for himself how far they are conformable to truth and reason. If they are not in accordance with facts, and the established principles of science, they will of course sink into oblivion ; but, if they are fair deductions from well-known phenomena, the cavils of pretended philosophers will be in vain, for truth and nature must triumph over all opposition. We have endeavored to interpret the great volume of nature, as its pages are unfolded to the view of every inquiring mind.

166. It may be said that we have not sufficiently verified our doctrines by experiments ; to which we answer, that nature has performed, and is continually exhibiting the most satisfactory experiments on a scale of grandeur and fidelity, which, by our manipulations, we can only *imitate* in a feeble manner. We have drawn our proofs and illustrations from the most familiar operations around us—from the silent combustion of a candle, to the magnificent displays of aerial lightning.

167.. It is acknowledged by all parties, that no previous

theory has been sufficient to explain the phenomena of magnetic polarity, to say nothing of the hypothetical character of the data on which they are founded; while it must be conceded by every candid individual, *that we have assumed no hypothesis as the basis of our theory.*

168. Professor Farrar of Cambridge, in a recent work on Electricity and Magnetism, makes the following observations. "The account which we have given of the present state of our knowledge, respecting the magnetism of the globe, will serve to show our imperfect acquaintance with this subject. And ignorant as we are, of a great many necessary data, especially of such as relate to the magnetic declination, we cannot expect to discover the *real cause of these phenomena.*"

169. If we have not unfolded all the relations of caloric and electricity, we have at least proved that without caloric, there is no electricity; so that if the agency of electricity be admitted, we must also admit the agency of caloric. We pretend not to have left nothing yet to be discovered in this immense science. Far from it. Sir Isaac Newton, himself, left much to be done by his successors, before the laws of gravitation were perfectly unfolded. But we *have shown*, that all the phenomena of magnetic intensity, variation, and dip, are in perfect accordance with our views. What more could be expected from any theory, than that it be founded on facts, and that it should explain the phenomena? Moreover, this theory explains a great variety of phenomena in meteorology, hitherto involved in mystery.

170. Mr. Herschell observes, in his late beautiful work on natural philosophy, in reference to the problem of polarity, that "the numerous experiments in electro-magnetism, show us

that there is light, could only a certain veil be drawn aside." We humbly trust, that we have in some measure, withdrawn this veil, by showing the origin of atmospheric electricity, its relations to caloric, and their unequal distribution in the tropical and polar regions.

171. We shall conclude with a quotation from Sir Humphrey Davy. "The more the phenomena of the Universe are studied, the more distinct their connection appears, the more simple their causes, the more magnificent their design, and the more wonderful the wisdom and power of their Author." (*Elements of Chemical Philosophy.*)

POSTSCRIPT.—The intelligent reader must have discovered a striking analogy between the laws of gravitation, and those of cohesive, capillary, chemical, and magnetic attractions. For example, that they all operate with a force inversely, as the squares of the distance; and that the same law is predicable of caloric and electricity.

Sir Isaac Newton resolved "the action of large masses of matter into the actions of their minutest particles or atoms; considering these particles as centres of force." Now if cohesive, capillary, chemical and magnetic attractions are owing to the agency of caloric, as we have endeavored to prove—and if they are only modifications of the cause of gravitation, it necessarily follows, that caloric is "*the bond of union among the heavenly bodies.*" (See Sec. 147, Part I.)

We have shown (Section 6, Part 1.) that the attraction of caloric for ponderable matter is inversely as the amount of its caloric. For example, the attraction of caloric for frozen mercury, is greater than for fluid mercury—it is also stronger for ice than for water at the same temperature; because water contains 140° more latent caloric than ice. M. M. Du Long and Pettit have estimated the specific caloric of all bodies having an equal number of atoms, to be the same—whether the atoms be larger or smaller—and it has been demonstrated that an atom of gold, is four times as large as an atom of iron, which explains why the specific gravity of gold, is four times that of iron—and as its attraction for caloric is increased in proportion to the diminished quantity of caloric which it contains, its actual gravitating force follows the same ratio. In other words, the gravitating power of gold, is in proportion to the size of its atoms, and to the *diminished* quantity of

caloric between them—while that of the lighter metals, stones, wood, furs, silks, gasses, and all other bodies, is less in proportion to the increased quantity of specific caloric which fills their pores, and to the diminished size of their atoms. Is this not the rationale of GRAVITATION? Does its power not increase at given distances, in proportion to the number and size of the ponderous atoms of different bodies, and to the diminished quantity of their specific caloric? And does it not follow from the above facts and reasonings, that the force by which the planets and comets are attracted towards the sun, is proportional to the number and size of their ultimate atoms, and to their respective distances from him?

The following paragraph should be read after section 93, part I.:—

An argument which proves still more conclusively than any we have employed, the identity of caloric and electricity, is deducible from the operations of a common electrical machine. It has been a generally received doctrine, since the days of Franklin, that in charging a Leyden jar, with a common electrical machine, the igneous fluid was drawn from the earth—and that a conducting chain, or wire, from the rubber to the ground or floor was necessary. Dr. Franklin thought that electricity was pumped up from the earth, by the revolutions of the cylinder. Dr. Hare has recently demonstrated, (*See American Journal of Science, July, 1833,*) that a battery may be charged as readily when the machine is perfectly insulated, as when connected with the ground by a conductor—from which it is obvious, as we had long ago suspected, that the electric fluid is obtained from the *atmosphere*—and that it is nothing more nor less, than the *latent caloric of the atmosphere, forced out during its condensation between the cylinder and rubber.* Dr. Hare seems not to have taken this view of the subject—he thinks, that “the effect of the machine is merely to transfer the fluid from one surface of the Leyden battery to another.” We are, however, greatly indebted to him, for correcting the above error, which, for a long time, has greatly obscured the subject of electricity.

A P P E N D I X.

THE following tables, constructed from the best authenticated observations of different individuals for the last two hundred and fifty years, down to the year 1818, were collected by Christian Hansteen, Professor of Astronomy in the University of Norway, and published a few years ago in his work on the Magnetism of the Earth. We have copied them from the Edinburgh Philosophical Journal, and from Sir David Brewster's Journal of Science.

In addition to what we have already said in the text on the subject of magnetic variation, we shall present the reader with the following observations of Professor Hansteen on the monthly, daily, and hourly variations of the needle.

"In addition to its annual movement, the needle has likewise a sensible movement from day to day, and even from hour to hour. In Europe, it lies farthest to the east about eight or nine o'clock in the morning, farthest to the west about one or two o'clock in the afternoon; it next travels back eastward till about eight or nine o'clock in the evening, when it continues stationary for an hour or two, or else makes a slight recoil towards the west; during the night it commonly advances a little eastward, so that about eight in the morning, it is found somewhat more easterly than it was the preceding evening.

"The common daily movement about the summer solstice, is nearly twice as great as about the winter solstice: at the former season about $\frac{1}{4}$, at the latter $\frac{1}{8}$ of a degree.* There is likewise a regular monthly movement, such as that from the summer solstice to the vernal equinox, the needle travels westward; eastward from the vernal equinox to the summer solstice.

* See Section 122, Part II.

"The regular daily movement is smaller near the equator, and increases onward to the pole.* The needle's eastermost or westermost position does not happen at the same instant, nor even at the same hour, in places very distant from each other. Its westermost position is reached in Iceland and Greenland, at from eight to ten in the evening; in Europe and the American United States, from two to three in the afternoon; in Sumatra about seven in the morning, in St. Helena about eight. Its eastermost position is attained in Europe and North America about seven or eight in the morning, in Iceland and Greenland about nine or ten; in Sumatra about five in the evening, at St. Helena, about six (or two.) On the north-west coast of America, the westermost position seems to occur in the forenoon, the eastermost in the afternoon."

"Those daily oscillations, in fine, appear to consist of four movements, two directed eastward, two westward. During the continuance of the aurora borealis, the intensity of the earth's magnetic force seems to grow weaker, for which reason the needle recedes from that magnetic pole where the ring of the aurora is displayed." (See *Edinburgh Philosophical Journal*, vol. IV., p. 119 and 20.)

From the numerous facts exhibited in these tables, the reader will be prepared to draw his own conclusions. In a subsequent part of this appendix, will be found, other tables, representing the observations of Sir W. E. Parry, from the year 1819, up to the year 1824,—also, tables of the dip or inclination of the needle in different parts of the globe. All which, we offer as a general guide to future observers. The latitudes and longitudes have been omitted as they were in the *Edinburgh Philosophical Journal*, because of the space which they would occupy; and as they can be easily ascertained by a reference to Maps, Gazetteers, &c.

* See Section 119, Part II.

TABLE I. Containing the Variation of the Needle, as observed
in Denmark, Norway, and Sweden.

NAMES OF PLACES.	Year of Observa-tion.	Magnetic Variation.	NAMES OF PLACES.	Year of Observa-tion.	Magnetic Variation.
Arendal,	1796	20° 21' W.		1774	16° 27' W.
Arboga,	1799	17 25		1775	16 37
Avestad,	1799	17 40		1775	16 20
Bergen,	1768 {	19 20		1775	16 33
	1791	24 45		1775	16 26
	1792	25 30		1775	16 27
Bommel Island,	1792	24 52		1776	16 27
Bessested,	1780	34 30		1776	16 30
Christiansund,	1768	16 30		1776	16 30
Christiansand,	1794	22 0		1776	16 28
Christiania,	1761 {	15 15		1776	16 32
	1769	16 45		1777	16 20
	1816	20 15		1777	16 39
	1817	20 3		1779	17 5
Carlberg,	1799	17 5		1782	17 41
Carlscrona,	1716	11 15		1783	17 49
	1649	1 30 E.		1784	17 42
	1672	3 35 W		1784	18 0
	1730	10 37		1785	18 7
	1731	11 15		1786	18 9
	1765	15 5	Copenhagen,	1792	18 23
	1765	15 3		1793	18 15
	1767	15 7		1806	18 25
	1768	15 13		1807	18 21
	1768	15 0		1808	18 22
	1768	15 2		1809	18 22
	1768	14 50		1810	18 16
	1768	14 56		1812	18 17
	1769	15 30		1813	18 22
	1769	15 29		1813	18 11
	1769	15 34		1813	18 10
	1769	15 22		1813	18 14
Copenhagen,	1770 {	15 32		1813	18 8
	1770	15 32		1814	17 58½
	1770	15 32		1814	17 56
	1770	15 32		1814	17 56
	1770	15 37		1815	18 6
	1771	15 32		1815	18 3
	1771	15 42		1815	18 5½
	1771	16 2		1816	18 15½
	1772	16 17		1817	18 5
	1772	16 0		1817	17 55
	1773 {	16 12	Drontheim,	1761	13 50
	1773	16 16		1769	15 25
	1773	16 17		1770	15 30
	1773	16 22		1771	15 40
	1773	16 9		1772	16 6
	1773	16 20		1773	16 40
	1774	16 17		1774	16 46
	1774	16 20		1775	16 58
	1774	16 32		1776	17 30

TABLE I.—*Continued.*

NAMES OF PLACES.	Year of Observation.	Magnetic Variation.	NAMES OF PLACES.	Year of Observation.	Magnetic Variation.
Drontheim,	1777	17°45' W.	Stockholm,	1718	5°37' W.
	1778	17 50		1763	11 48
	1779	18 0		1764	11 58
	1780	18 0		1765	12 8
	1781	18 24		1766	12 15
	1782	18 30		1767	12 21
	1783	18 32		1768	12 28
	1783	18 30		1769	12 33
	1784	18 35		1771	13 4
	1786	19 0		1772	13 4
Dyrefjords Haven	1786	42 41		1775	13 20
Fahlun,	1799	18 45		1777	13 56
Flekkeröe,	1783	19 29	Salberg, Sala, Söderbärke, Sälö Bäk, Sädankyla, Skiervoens Ch'ch, Strömstad, Sulen Island, Talvig, Utsjoki, Upsal, Uhma Capel, Uranienburg, Wardhus, Vadsöe, Vangs Church, Vesteräs, Vinga Bäk,	1786	15 34
Fredericksborg,	1810	18 50		1787	15 17
Gottenburg,	1694	8 30		1800	16 20
Havnefjord,	1748	12 40		1811	15 52
Holmenshavn,	1786	35 21		1817	15 36
Hammerfest,	1786	43 9		1817	15 34
Hustappen Island	1765	6 50		1746	9 0
Hvalöers Church,	1766	7 0		1799	16 0
Hveen Island,	1768	16 25		1746	9 15
Helsingörer,	1672	2 35		1804	18 30
Hedmora,	1761	14 0		1776	5 30
Jukasjerwi,	1748	9 10		1768	16 30
Kielvigs Church,	1776	11 30		1804	18 0
Karasjok,	1766	5 30		1791	27 15
Kongswinger	1768	6 50		1766	6 50
Kullens,	1779	17 30		1695	7 0
Köping,	1803	21 0		1736	5 5
Nya Kopparb'rg't	1799	17 15		1748	7 30
Kongsör,	1799	17 25		1767	8 50
Kusamo Church,	1746	9 30		1777	11 45
Lindesness.	1776	5 30		1748	3 30
Lofoeden Isles,	1605	7 10 E.		1718	5 37
	1608	0 0		1740	8 49
Lund Pfarrhof,	1609	0 0		1746	8 45
Lyderhorn,	1785	19 30 W.		1762	10 45
Lindesberg,	1768	19 20		1672	2 35
North Cape,	1746	9 36	Utsjoki, Upsal, Uhma Capel, Uranienburg,	1748	0 0
Nora,	1769	6 0		1775	0 30
Norrberke,	1799	18 35		1775	5 32
Orebroe,	1799	17 35		1748	0 30
Patrixfjord,	1799	17 7	Wardhus, Vadsöe, Vangs Church, Vesteräs, Vinga Bäk,	1748	1 0
Rust Island,	1772	33 30		1816	7 55
Stavanger,	1613	4 8 E.		1793	19 50
Skudesness,	1794	22 26 W.		1799	17 50
Stadthuk,	1613	8 0 E.		1804	19 0
	1768	19 10 W.			
	1790	25 45			

TABLE II. *Containing the variation of the Needle in Russia.*

NAMES OF PLACES.	Year of Observation.	Magnetic Variation.	NAMES OF PLACES.	Year of Observation.	Magnetic Variation.
Awatscha Bay,	1805	5°39' E.	Neschin,	1729	10° 0' W.
Barranno Kamen	1787	17 40	-	1782	10 0
Barnaul,	1770	2 45	Orenburg,	1769	3 30
Casan,	1761	2 25W.	-	1769	3 20
-	1805	2 2 E.	Orsk,	1769	0 15
Catharinenburg	1761	0 50	-	1781	9 0
-	1805	5 27	Orel,	-	1726
Carchow,	1783	7 27W.	-	1727	3 15
-	1811	5 17	-	1730	2 30
Cherson,	1782	10 10	-	1741	4 4
Caffa,	1772	7 0	-	1755	3 56
Dmitrewsk,	1771	5 49	Petersburg,	1772	4 30
-	1773	6 30	-	1774	4 50
Druia,	1773	10 40	-	1782	7 30
St. Elizabeth,	1770	9 45	-	1784	7 30
Gluchow,	1770	5 30	-	1797	8 13
Gurief,	1769	3 25	-	1805	9 12
Gloubouca,	1615	18 0	-	1806	11 0?
-	1768	5 15	-	1811	7 52
Jakutskoi,	1769	5 0	-	1812	7 36
-	1788	2 0	Perm,	1805	7 16
-	1735	1 15	Petropaulowska	1779	1 10 E.
Irkutsk,	1735	1 19	-	1805	6 19
-	1805	0 32 E.	Petrosawodsk,	1785	5 20
Jarowslawl,	1782	4 0W.	Ponoi,	1769	5 9W.
Jenicola,	1785	7 15	Peczora,	1611	1 10 E.
-	1769	2 15	Pustozerskoi,	1614	22 30W.
Kola,	1769	1 45	Revel,	1751	20 0
-	1769	1 45	Riga,	1750	7 30
-	1769	1 45	Samara,	1770	8 0
Krementschuk,	1770	8 0	Sietscha,	1770	8 10
-	1735	2 0	Sisran,	1770	9 15
Krasnojarsk,	1735	1 0	Selenginsk,	1735	5 50
-	1735	1 45	-	1735	0 0
-	1735	1 30	-	1735	0 30
Kiachta,	1735	3 0	Saratow,	1735	2 45
-	1735	2 45	Sewastropol,	1773	5 28
Kiow,	1773	9 15	Tscherkask,	1785	11 13
Kaluga,	1784	7 45	Tara,	1770	5 50
Kursk,	1784	5 0	Tomsk,	1805	6 6 E.
Kostroma,	1782	3 45	-	1805	5 37
Kesloff or Kozlov,	1785	11 38	Tobolsk,	1716	0 0
-	1782	9 5	-	1761	3 46
Moscow,	1732	5 26	-	1805	7 9
Mosdok,	1785	6 40	Tanbow,	1784	5 45W.
Nezhni Kovima,	1787	14 40 E.	Umba,	1769	3 30
-	1735	3 15W.	Ufa,	1769	1 30 E.
Nizni-Udinsk,	1805	2 40 E.	Ustkamenogorskoi,	1770	2 0
Nertschinsk,	1735	3 0W.	Wologda,	1785	3 52W.
-	-	-	Woronetz,	1783	8 0
-	-	-	Zarizin,	1770	4 50

TABLE III. Containing the Variation of the Needle in Holland, Prussia, the Netherlands, and Switzerland.

NAMES OF PLACES.	Year of Observation.	Magnetic Variation.	NAMES OF PLACES.	Year of Observation.	Magnetic Variation.
Antwerp, -	1600	9° 0' E.		1801	21° 26' W
Amsterdam, -	1767	17° 30' W.		1802	21 27
Augsburg, -	1772	16 40	Geneva, -	1803	21 18
	1798	18 26		1804	21 13
	1717	10 42	Grätz, -	1770	15 50
	1717	10 52	Göttingen, -	1777	16 48
	1724	11 45	Hague, -	1782	20 16
	1725	11 56	Inspruek, -	1787	22 40 ?
	1725	11 52		1600	0 0
	1751	14 16		1628	1 0
	1764	14 15	Konigsberg, -	1642	1 5
	1770	16 9		1774	13 30
	1773	16 48	Leipsic, -	1749	13 0
	1774	16 54		1776	19 48
	1775	17 1½		1785	19 44
Berlin, -	1777	16 42	Manheim, -	1786	19 53
	1777	16 45		1787	20 2
	1777	16 42		1788	20 5
	1778	16 45	Mittau, -	1783	10 52
	1779	16 46½	Middleburg, -	1786	21 14
	1780	16 48		1788	21 56
	1782	17 47	Nuremberg, -	1685	5 5
	1783	17 51		1774	15 45
	1784	17 57		1775	16 15
	1785	18 3	Prague, -	1781	16 50
	1786	18 20		1782	17 44
	1787	17 44		1786	18 9
	1788	17 5		1787	17 20
	1805	18 5	Rotterdam, -	1767	19 0
	1805	17 57		1784	17 49
	1805	18 2	Regensburg, -	1785	19 1
	1782	17 20		1786	19 11
Bonne, -	1784	17 41		1747	13 34
	1787	18 1		1748	14 22
	1788	18 55	Tübingen, -	1749	14 45
	1628	1 0		1750	14 30
	1642	3 15		1752	14 37
Dantzig, -	1670	7 20	Tankermund, -	1814	19 0
	1682	8 48	Vienna, -	1638	0 0
	1760	11 0		1760	13 0
	1811	13 48		1781	18 40
Dusseldorf, -	1783	20 0		1782	18 40
Dresden, -	1797	18 30		1783	18 39
Freyberg, -	1769	15 40	Wurtzburg, -	1784	18 30
Frkf't-on-Mayne,	1774	16 32		1785	18 33
Franeker, -	1771	19 30		1786	18 31
	1773	18 30	Zurich, -	1787	18 35
Geneva, -	1797	19 40		1762	15 15
	1800	21 30			

TABLE IV. Containing the Variation of the Needle as observed
in France.

NAMES OF PLACES.	Year of Observation.	Magnetic Variation.	NAMES OF PLACES.	Year of Observation.	Magnetic Variation.
Antibes, -	1682	3°40'W		1700	7°40'W
Bayonne, -	1680	1 20		Nov.	8 12
Boulogne, -	1767	17 26		1701	8 25
	1679	1 45		Sept.	8 48
Brest, -	1771	20 10		1702	8 48
	1798	25 30		Oct.	8 50
Calais, -	1681	4 30		1703	9 0
	1767	19 30		Dec.	9 6
Dieppe, -	1619	6 30 E.		1704	9 20
Dunkirk, -	1767	18 33W.		1704	9 20
Havre de Grace,	1767	19 15		1705	9 25
	1782	22 15		July	9 30
Marseilles, -	1761	18 0		Dec.	9 35
	1798	20 55		Dec.	10 0
St. Maloes, -	1681	2 0		1706	9 48
Montpellier, -	1674	1 10		1707	10 10
Ushant Island,	1776	23 1		1708	10 15
	1541	7 0 E.		Dec.	10 15
	1550	8 0		1709	10 40
	1580	11 30		Dec.	10 30
	1603	8 45		1710	10 50
	1610	8 0		Dec.	10 50
	1630	4 30		1711	11 0
	1640	3 0		Dec.	10 50
	1642	2 30	Paris,	1712	11 25
	1659	2 0		Dec.	11 15
	1660	1 0		1713	11 40
	1664	0 40		Dec.	11 12
	1666	0 0		1714	12 0
	1667	0 15W.		Dec.	11 30
	1670	1 30		1715	11 10
	1680	2 40		1716	12 15
	1681	2 30		Oct.	12 30
Paris,	1682	2 30		Dec.	12 30
	1683	3 50		1717	12 45
	1684	4 10		Dec.	12 40
	1685	4 10		1718	12 30
	1686	4 30		Dec.	12 30
	1687	5 12		1719	12 30
	1688	4 30		1720	13 0
	1689	6 0		1721	13 0
	1691	4 40		Oct.	13 0
	1692	5 50		1722	13 0
	1693	6 20		Nov.	13 0
	1695	6 48		1723	13 0
	1696	7 8		Dec.	13 0
	1697	7 40		1724	13 0
	1698	7 40		1725	13 0
	1699	7 50		Oct.	13 15
	Oct.	8 10		Dec.	13 15

TABLE IV.—*Continued.*

NAMES OF PLACES.	Year of Observa-tion.	Magnetic Variation.	NAMES OF PLACES.	Year of Observa-tion.	Magnetic Variation.
	1726	13°45'W		Dec.	20°41'W
	1727	14 0		1779	20 31
	1728	13 50		June	20 35
	1729	14 10		July	20 33
	1730	14 25		Aug.	20 40
	1731	14 45		Aug.	20 31
	1732	15 15		Nov.	20 35
	1733	15 45		1780	20 35
	1734	15 35		Mar. 27.	20 45
	Dec.	15 40		May 5.	20 40
	1735	15 45			16 20 42
	Oct.	14 55			17. 20 49
	1736	15 40			18. 20 42
	Dec.	15 40			19. 21 4
	1737	14 45			20. 20 49
	1738	15 10			21. 20 45
	Feb.	15 20			22. 20 42
	1739	15 30			23. 20 57
	1740	15 45			24. 20 44
	Dec.	15 30			25. 20 48
	1741	15 40			26. 20 46
	1742	15 40			27. 20 47
Paris,	Sept.	15 10	Paris,	June	28. 20 43
	1743	15 10			29. 20 47
	1744	16 15			31. 20 42
	1745	16 15			June 1. 20 45
	1746	16 15			2. 20 45
	1747	16 30			3. 20 48
	1748	16 15			4. 20 39
	1749	16 30			5. 20 49
	1750	17 15			7. 20 39
	1751	17 0			9. 20 39
	1752	17 15			13. 20 48
	1753	17 20			16. 21 4
	1754	17 15			18. 20 43
	1755	17 30			19. 20 45
	1757	18 0			22. 20 54
	1758	18 0			24. 20 50
	1759	18 10			25. 20 42
	1760	18 30			26. 20 39
	1765	19 0			27. 20 42
	1770	19 55			28. 20 38
	1771	19 50			30. 20 44
	1772	20 12		July	3. 20 36
	Nov.	20 2			5. 20 51
	1773	20 4			7. 20 39
	Apl.	20 0			8. 20 44
	1774	20 17			Aug. 16. 21 0
	Aug	20 12			Sept. 19. 20 45
	1777	20 27			21. 20 50
	1778	20 37			22. 20 42

TABLE IV.—Continued.

NAMES OF PLACES.	Year of Observation.	Magnetic Variation.	NAMES OF PLACES.	Year of Observation.	Magnetic Variation.
Paris,	Sept. 23.	20° 46' W	Paris,	1798	22° 17' W
	Dec. 19.	20 56		1799	22 49
	1781	20 47		1799	22 0
	Jan. 27.	20 40		1800	22 12
	Mar. 7.	20 47		1801	22 1
	April 1.	20 59		1802	21 45
		17. 20 50		1802	22 3
	May 8.	20 51		1802	21 45
	12. & 29.	20 51		1803	21 59
	June 23.	20 57		1804	22 5
	Oct. 8.	21 3		1804	22 15
		1782 21 1		1807	22 34
	June 28.	21 16		1814	22 34
	July 4.	21 12		1816	22 25
	1783	21 12		1817	22 17
	June 23.	21 22		1818	22 21, 6
	Aug. 5.	21 27		1819	22 29
		1784 21 27		1680	1 20
	Feb. 29.	21 24.		1682	3 45
		1785 21 35		1747	15 10
		1786 21 37		1748	15 0
	June 21.	21 27		1749	15 10
		1789 21 56		1750	16 5
		1790 22 0		1751	16 0
		1790 21 52		1752	15 45
		1791 22 2		1753	16 45
		1791 22 4		1754	16 40
		1792 22 45		1755	15 0
		1793 22 49		1756	15 45

TABLE V. Containing the Variation of the Needle, as observed in Great Britain and Ireland.

NAMES OF PLACES.	Year of Observation.	Magnetic Variation.	NAMES OF PLACES.	Year of Observation.	Magnetic Variation.
Bristol,	1666	1° 27' W	Dublin,	1745	18° 0' W.
	1667	1 33		1751	19 0
	1813	24 22 17		1772	23 30
	1814	24 22 48		1786	26 21
	1815	24 27 18		1788	26 50
	1817	24 42 14		1790	27 15
	1818	24 45 11		1791	27 23
Bushey Heath,	1819	24 41 41	Edin- burgh,	1804	26 30
	1820	24 39 16		Oct. 29.	1808* 27 31 49"
	1820	24 36 34		Nov. 3.	1809* 27 35 10
	1822	24 35 26		Sept. 29.	1812* 28 8
				July 9.	1823† 27 48

* According to Mr. James Jardine's observations.

† According to Professor Wallace's observations.

TABLE V.—Continued.

NAMES OF PLACES.	Year of Observation.	Magnetic Variation.	NAMES OF PLACES.	Year of Observation.	Magnetic Variation.
Hermitage Hill,*	1823	27° 0' W.		1795	23° 57' W.
	1580	11 15 E.		1796	24 0
	1722	5 56½		1797	24 1
	1634	4 6		1798	24 0,6
	1657	0 0 W.		1799	24 1,8
	1665	1 22½		1800	24 3,6
	1672	2 30		1801	24 4,2
	1692	6 0		1802	24 6,7
	1723	14 17		1803	24 8,8
	1745	17 0		1804	24 8,4
	1745	17 0		1805	24 8,8
	1746	17 10		1809	24 11,0
	Dec. 18.	17 25	London,	-	1814 24 16,7
London	1747	17 30		July	24 17,9
	1747	17 40		Aug.	24 21,2
	1748	17 40		Sept.	24 20,5
	1773	21 9		1815	24 17,8
	1774	21 16		1816	24 17,9
	1775	21 43		1817	24 17
	1786	23 17		1818	24 15,7
	1787	23 19		1819	24 14,8
	1788	23 32		1820	24 11,7
	1789	23 19		1821	24 11 18"
	1790	23 39		1822	24 9 55
	1791	23 36	Plymouth,	-	1823 24 9 48
	1792	23 36		unkn'n.	13 24 E.
	1793	23 49		1733	13 27 W.
	1794	23 56	Stromness Harbor,	1774	24 0

From the preceding tables, it will be perceived that a remarkable shifting of the variation in the North of Europe, has marked different periods. For example, from the year 1718, when the variation was 5° 37' W., at Stockholm, until 1800, when it was 16° 20', the westerly variation increased—some years, however, more than others; but from 1800 until 1817, there was a slight retrograde movement in the variation. The irregular shifting of the variation at St. Petersburg, is still more obvious. In the year 1726, the westerly variation was 3° 15', while in 1727 it was 2° 30', showing a retrograde or easterly movement—three years afterwards, it was 4° 4' W.—and eleven years later, it was 3° 56', showing another slight retrograde movement. In 1784, it was 8° 13', and in 1805, it was 11°,—but the next year it had shifted backwards, or easterly, 3° 48'—from which it is evident, that the

* Near Leith, according to Mr. Andrew Waddell's observations.

shifting of the Magnetic Variation has not the regularity or uniformity which belongs to revolutionary movements.

In the year 1580, the variation was $11^{\circ} 30'$ E., at Paris; while in 1666, it was nothing. From that time until 1819, it advanced westerly, but without much regularity—sometimes remaining nearly stationary for many years. For more than a hundred years, while the variation was easterly at Paris, the needle must have obeyed a magnetic pole in the North of Asia, and not the American pole as at present. The same is true in regard to the variation at London during the same period.

TABLE VI. *Containing the Variation of the Needle as observed in Portugal, Spain, and Italy.*

NAMES OF PLACES.	Year of Observation.	Magnetic Variation.	NAMES OF PLACES.	Year of Observation.	Magnetic Variation.
Aranjuez, -	1798	19°25'W.		1706	6°30'W
Alborne Island,	1733	14 12	Lisbon,	1762	17 32
Braga, -	1761	16 15		1776	19 0
Brescia, -	1676	4 0 E.		1782	19 51
	1724	5 25 W	Loretto, -	1756	15 35
	1769	17 15	Madrid, -	1799	19 59
Cadiz, - -	1769	18 40		1694	9 15
	1771	18 0	Malta, -		9 45
	1776	19 42		1708	10 25
	1791	21 56	Minorca, C. Mola,	1733	14 34
Cape St. Vincent,	1733	13 49		1725	13 0
Cape St. Gatt, Sp.	1733	13 56	Padua, -	1730	13 0
Cape St. Mary's, P.	1734	14 20		1770	16 20
Cape Finisterre, {	1589	7 40 E.		1670	2 15
Cape Finisterre, {	1768	21 4 W		1681	5 0
Cape St. Antonio, S.	1792	19 23		1695	7 30
Ferrara, -	1677	2 0		1730	11 0
	1733	13 38	Rome, -	1782	16 49
Gibraltar Bay, {	1761	17 11		1783	16 49
	1792	22 6		1784	16 54
	1638	7 39 E.		1785	17 0
Lisbon, - -	1668	0 50 W		1786	17 4
	1683	3 0		1787	17 7
	1697	4 18		1788	17 12

TABLE VII. Containing the Variation of the Needle, as observed in Turkey in Europe.

NAMES OF PLACES.	Year of Observa-tion.	Magnetic Variation.	NAMES OF PLACES.	Year of Observa-tion.	Magnetic Variation.
Akiermann,	1771	9°25'W			
Bender,	1772	9 45			
Bucharest,	1772	11 36			
	1600	0 0	Ofen,	1781	16°45'W
	1625	2 0		1783	15 58
Constantinople,	1694	9 0		1782	15 36
		12 0		1784	15 40
				1785	15 48
				1787	16 26
				1788	16 36

TABLE VIII. Containing the Variation of the Needle as observed in Asia and the adjacent Islands.

NAMES OF PLACES.	Year of Observa-tion.	Magnetic Variation.	NAMES OF PLACES.	Year of Observa-tion.	Magnetic Variation.
Al'x'ndretta, Syria,	1694	14°22'W	Celebes, Bonthain,	1767	1°16'W
	1612	13 40	Chaul, India,	1721	5 27
	1612	12 40		1601	16 0
Aden, Arabia,	1674	15 0		1612	14 0
	1723	13 50		1612	14 30
	1723	13 42		1620	14 20
Ava, India,	1689	5 0	Cape Comorin,	1680	8 45
Aleppo, Syria,	1781	12 30	India,	1688	7 30
Alguarda, n'r Goa,	1722	5 49		1723	2 51
Anjanga, India,	1724	4 17		—	2 48
Bab-el-Mandeb,	1723	14 20		—	2 50
	1723	14 8		—	3 9
Baixos de Chago Island,	1610	19 50	Ceylon,	1722	2 12
Beit-el-Fakih,	1762	11 50	Friar's Hood,	1722	2 21
Bachian Island,	1612	4 48 E.	Point de Galle	1613	13 24
Amasane Bay,				1723	2 46
	1676	12 0W.		1723	2 45
	1721	5 12		1731	3 0
Bombay, India,	1721	5 16		1735	2 0
	1722	5 7	Chandernagore,	1743	1 20
	1723	5 10	India,	1745	1 0
Banca Island,	1791	0 0		1747	0 0
Balasore, India,	1680	8 20		1750	0 0
Do.Cape Palmiras,	1722	3 33		1614	15 0
Calicut,	1722	4 5		1706	6 20
	1772	4 9	Cochin, India,	1722	3 34
Canton,	1690	2 25		1722	3 53
	1722	1 30		1724	3 26
	1722	5 40		1724	4 16
Carwar Bay, India,	1722	5 4	Daman, India,	1612	16 30
	1723	5 8	Dabal, India, -	1610	15 34
	1724	5 32		1611	16 30

TABLE VIII.—Continued.

NAMES OF PLACES.	Year of Observation.	Magnetic Variation.	NAMES OF PLACES.	Year of Observation.	Magnetic Variation
Derbent, Persia,	1712	12° 0' W.	Mazeira Is. Arabia,	1613	20° 10' W
Darsina, Arabia,	1612	15 2	{ Mocha, Arabia,	1723	13 34
Doy or Doq, Mo-	1613	5 20 E.	{	1769	12 33
lucca Islands,			{	1776	11 20
Firando, an Isl'd near Japan,	1613	2 50	Mindanao, Cape	1767	1 45 E.
	1609	16 0 W.	St. Augustin,	1685	0 0 W.
	1706	6 40	Nankin, China,	1605	7 5
Goa, India,	1722	4 57	Nicobar, India,	1611	13 15
	1723	5 13	Paliacate, India,	1613	13 10
	1723	5 3		1611	12 47
	1724	5 41	Patapilli, India,	1611	12 22
Guadal Cape, Persia,	1613	17 15		1613	13 50
Hainan Isl. China,	1616	18 0	Pondicherry,	1689	7 0
Hyderabad,* 27th June,	1613	0 50	Princes Island,	1767	1 0
Bantam,	1804	1 16.39 E	near Java,	1760	0 54
Java, Batavia,	1609	3 0 W.	Pulo Condore,	1620	1 0
	1767	1 25	Island,	1780	0 14
	1768	0 25	Pekin,	1755	2 0
Palimbang	1605	3 20	St. Paul's Island,	1677	23 30
[spahan, Persia,	1787	7 30	Roquepiz, Island,	1610	23 30
[riseh,	1797	8 14	Rogipore (Raja-pur,)	1722	4 58
Ingana Island,	1607	4 13	Rasalgat Cpe. Arb.	1613	19 20
Jask Cape, Persia,	1616	19 20	Sually,	1610	16 40
Judda, Arabia,	1769	11 52	-	1611	16 30
Kashin, Persia,	1776	12 55	Sunda Strait,	1612	17 0
Kerguelen's Land,	1787	7 33	Sinde,	1615	3 30
Louveau, Siam,	1776	27 44	Sinope,	1613	16 45
	1685	4 45		1797	10 18
	1685	0 30 ?		1611	16 23
	1686	4 45	Surat,	1612	16 50
Lucepara Island,	1688	4 30	-	1722	5 50
	1767	0 0		1723	5 59
Macao	1616	1 30	Singanfu, China,	1723	5 22
	1685	4 0 ?	Sumatra,	1689	3 17
	1779	0 32	Achen,	1610	6 25
Madras, India,	1722	2 52	Marlborough	1794	1 10 E.
Madura Island,	1723	3 16	Fort,	1795	1 8
near Java,	1768	0 30	Priaman,	1612	4 10 W.
	1722	5 24	-	1613	4 50
Mangalore, Ind.	1722	5 35	Tellicherry, Ind.	1722	4 21
	1723	5 5		1722	4 4
Masulipatam, Ind.	1610	12 22	Tiiz,	1613	18 30
Machian Island,	1612	4 12 E.	Tecu Island,	1612	4 40 E.
near Gilolo,	1613	3 28	Xin-Yam, China,	1682	0 0 W.
Maldevische-Ca-	1605	17 0 W.	Ula, China,	1682	1 40 E.
nal,	1722	4 16	-		

* This is the mean of two observations made at the Camp near Hussain Sanger, by Lieut. Col. Morison, and communicated to me by John Robison, Esq.

TABLE IX. Containing the variation of the Needle, as observed in Africa and the adjacent Islands.

NAMES OF PLACES.	Year of Observation.	Magnetic Variation.	NAMES OF PLACES.	Year of Observation.	Magnetic Variation.
Alexandria, Egypt,	1638	5° 45' W	Comora Islands, Angoxa, on c'st. of Africa,	1611	13° 0' W
	1761	11 4		1721	19 12
	1798	13 6		1721	19 44
	1678	1 0 E.		1721	20 33
	1754	8 6 W.		1722	20 39
Ascension Isl'd.	1768	9 53	Anjouan, - Mayotta, - Molalio, -	1722	20 33
	1775	10 52		1722	21 12
	1806	15 40		1722	20 24
	1726	11 25		1611	15 20
Accara, Fort Guinea, Angoxa, Ab-dal-Curia Is.	1726	11 53	Cape Verd Islands, Porto Praya, St. Jago,	1725	4 5
	1611	12 1		1766	8 20
	1612	17 23		1766	8 20
	1723	12 43		1772	10 45
Algiers, Barbary, Azores Islands, Fayal Bay, -	1731	14 0	Mayo, - Sal,	1791	14 12
	1589	3 5 E.		1725	3 32
	1775	22 7 W.		1776	9 32½
	1600	0 0		1610	3 30 E.
Flores, - Marie, -	1610	1 40 E.	Cairo,	1694	12 15 W.
	1723	14 20 W.		1761	12 25
	1723	14 8		1762	11 40
	1610	19 50		1798	12 0
Bab-el-Mandeb, Baxos de Chagos, Bourbon Isle of, Mascarenhas,	1614	22 48	Damietta, Egypt, Doara, Ajan,	1694	12 30
	1722	19 49		1611	17 36
	1722	19 44		1611	17 20
	1616	13 12		1776	26 15
Boobam, Cape Coast, -	1726	11 55	Prince Edward's Island, -	1609	21 0
	1726	12 10		1722	18 46
	1726	11 46		—	18 39
	1724	5 0		—	19 7
Canary Islands, Ferro, -	1769	17 30	France, Isle of, (Mauritius),	—	19 45
	1802	19 55		1609	0 12
	1610	6 6 E.		1605	0 30 E.
	1727	6 58 W.		1614	1 30 W.
Lanzarote, - Madeira, Fun- chal, -	1766	14 10	Cape Good Hope, Cape l' Agu- illas,	1650	22 16
	1766	16 0		1614	23 40
	1771	18 0		1780	1 45
	1783	18 22		1614	7 15
Grand Canary,	1802	20 21	Saldanha Bay, Simon's Bay,	1675	8 28
	1610	6 6 E.		1687	8 30
	1769	15 43 W.		1699	11 0
	1770	15 30		1702	12 50
Teneriffe, Sta Cruz,	1776	14 41	Table Bay,	1706	13 40
	1776	15 55		1708	14 0
	1785	15 52		1721	16 25
	1788	20 1		1724	16 27
	1792	16 32			
	1803	16 1			

TABLE IX.—*Continued.*

NAMES OF PLACES.	Year of Observa- tion.	Magnetic Variation.	NAMES OF PLACES.	Year of Observa- tion.	Magnetic Variation.
Cape Good Hope,	1724	16° 18' W	Madagascar,	1661	22° 30' W
	1752	19 0	Antongill Bay	1761	18 0
	1768	19 30		1661	19 0
Table Bay,	1772	20 26	Fort Dauphin,	1761	22 7½
	1775	21 14	Foul Point, -	1762	16 45
	1788	23 16		1600	16 0
	1792	24 30	St. Sebastian,	1610	16 40
	1804	25 4	Cape,	1722	19 1
Gorée,	1682	0 0		1722	18 36
	1769	12 15		1610	19 50
	1772	10 30	St. Mary's Isl'd.	1722	19 53
	1610	17 35	n'r Madagascar,	—	19 52
Guardafui, Cape	1612	17 34	Nosf-Gombi, an	—	19 25
	1721	11 11	island near	—	20 0
	1723	12 34	Madagascar,	—	19 45
Hermanas Isl'd. n'r C. Guardafui,	1610	18 55	Salée Roads, -	1735	12 19
	1612	17 23	Sierra Leone,	1608	1 50 E.
	1600	8 0 E.	Sunken Rocks,	1725	5 12 W.
	1604	7 45	S. Lat. 31° 48',	1606	21 0
	1610	7 13		1611	16 0
	1623	6 0		1612	17 22
	1677	0 40		1674	17 0
	1691	1 0 W.		1723	11 25
St. Helena, Isl- and of,	1724	7 30	Socotra, Island	—	11 36
	1764	11 38	of,	—	11 38
	1768	12 47		—	12 4
	1775	14 18		—	11 57
	1785	12 18		—	12 20
	1789	15 30		—	8 6
	1796	15 48½	St. Thomas, Isle	1726	14 48
Madagascar,	1806	17 18	of,	1726	14 32
	1607	15 30	Tripoli,	1733	13 22
Augustin's	1607	15 26	Trinidad, Island	—	—
Bay,	1610	14 50	S. Lat. 20° 45,'	1615	12 0 E.
	1611	15 11	N. Long. 29° 30,'	—	—
	1613	15 40		—	—
	1721	23 48		—	—

Account of the Scientific Observations made during the Expedition under Captain Parry.

Taken from the Edinburgh Philosophical Journal.

1. *Magnetical Observations.*

As the measures of the variation and dip of the needle could be taken only on icebergs and islands, out of the reach of the ship's attraction, they are not so numerous as might have been expected; but they make up in importance for what they want in quantity, and will be studied with much interest by the philosophers of all countries. The following Table contains the whole of the results given in Captain Parry's work, and deduced from observations made principally by Captain Sabine.

Observations on the Variation of the Needle.

	NORTH Latitude.	West Longitude	Variation West.	
1819,				
June 19.	59°49'	48° 9'	48°38' 21"	On ice.
— 26.	63 58	61 50	61 11 31	On ice, 220 yards distant from
— 27.	63 44	61 59	60 20 12	On ice. [ship.
— 30.	63 26	62 9	61 50 12	
— 30.	63 29	62 8	60 55 48	On ice, 200 yards distant.
July 15.	70 29	59 12	74 39 0	
— 17.	72 0	59 56	80 55 27	On an iceberg.
— 23.	73 5	60 11½	82 2 40	On ice, 200 yards distant.
— 23.	73 3	60 12½	82 37 30	
— 24.	73 0	60 9	81 34 0	
— 31.	73 31	77 22½	108 46 35	Possession Bay.
Aug. 3.	74 25	80 8	106 58 5	Iceberg.
— 7.	72 45	89 41	118 16 27	E. coast of Regent's Inlet.
— 13.	73 11	89 22½	114 16 43	On ice.
— 15.	73 33	88 18	115 37 12	E. coast of Regent's Inlet.
— 22.	74 40	91 47	128 58 7	Beach at Cape Riley.
			EAST.	
— 28.	75 9	103 44½	165 50 9	SE. point of B. Martin's Island.
Sept. 1.	75 3	105 54½	158 4 13	On ice.
— 2.	74 58	107 3	151 30 3	
— 6.	74 47	110 34	126 17 18	
— 15.	74 28	111 42	117 52 22	
Winter Harbor	74°47' 13"	110 49 0	127 47 50	
1820,				
June 3.	75 6 52	110 27 40	128 30 14	
— 7.	75 34 47	110 35 52	135 3 55	
— 11.	75 12 50	111 51 54	125 15 22	
— 12.	75 5 18	111 56 58	123 47 58	
— 13.	75 2 37	111 37 10	126 1 48	
— 15.	74 48 33	111 11 49	123 5 30	
Aug. 5.	74 24	112 53	110 56 11	
— 10.	74 26	113 48	106 6 38	
— 18.	74 25	112 41	111 19 15	
— 25.	74 27	112 11	114 34 45	
Sept. 3.	71 16	71 18	91 28 32	W. coast of Davis' Strait.
— 7.	70 22	68 37	80 59 17	Inlet called River Clyde.

Observations on the Dip of the Needle.

	NORTH Latitude.	West Longitude	Dip.	
1819,				
March	51°31' "	0° 8'	70°33' 27"	Regent's Park, London.
June 26.	64 0	61 50	83 4 41	Ice, Davis' Strait.
July 17.	72 0	60 0	84 14 9	Ice, Baffin's Bay.
— 31.	73 31	77 22	86 3 7	Possession Bay.
Aug. 7.	72 45 15	89 41	88 26 71	E. coast of Regent's Inlet.
— 11.	72 57	89 30	88 25 17	On ice.
— 15.	73 33	88 18	87 35 95	N. Side of Barrow's Strait.
— 28.	75 10	103 44	88 25 58	B. Martin's Island.
— 30.	74 55	104 12	88 29 12	Ice, 400 yards distant from ship.
Sept. 6.	74 47	110 34	88 29 91	Beach, Melville Island.
— 11.	74 27	111 42	88 36 95	Melville Island.
1820,				
July 18.	74 47	110 48	88 43 5	Observatory, Winter Harbor.
Sept. 17.	68 30	64 21	84 21 42	Ice, Davis' Strait.
— 28.	51 43	0 14	70 33 5	Near London.

"The change in the direction of the variation from *Westerly* to *Easterly*, must have taken place about the 102d degree of west longitude, and shows that the expedition must at that point, which they passed on the 27th of August, have been a few degrees to the north of the Great Magnetic Pole. This conclusion agrees very wonderfully with the position of this pole, as assigned by M. Hansteen, who places it, in 1819, in 69° 40' of North Lat., (5° 23' to the south of the ships on the 27th August,) and in 90° of West Longitude."

"From the experiments made at Winter Harbor to determine the variation in the magnetic force, it appears that the time of vibration of Mr. Brown's dipping-needle decreased between London and Winter Harbor in the ratio of 481 to 446; and consequently, the force in the direction of the dipping-needle appeared to have increased in the ratio of 1.163 to 1."

"From the increase in the times of vibration of three horizontal needles between Sheerness and Winter Harbor, the force acting upon them appeared to have diminished in the ratio of 12.93 to 1; 13.23 to 1; and 13.83 to 1; the mean of which is 13.33 to 1."

APPENDIX.

Observations on the Dip of the Needle, made in different parts of the World,

COLLECTED BY PROFESSOR HANSTEEN.

(Taken from the fourth volume of the Edinburgh Journal of Science.)

PLACES OF OBSERVATIONS.	Dip.	PLACES OF OBSERVATIONS.	Dip.
	South.		
Port du Nord	75° 50'	St. Gotthardt	66° 22'
Port du Sud	70 48	Mont Cenis	66 22
Surrobaya in Java	25 40	Ursern	66 42
Amboina	20 37	Altorf	66 53
Lima	9 59	Atlantic } 37° 14' n. 3° 30' 0"	67 30
Magnetic Equator in Peru	0 0	Sea } 38 52 — 3 40	67 40
	North.	Madrid	67 41
Tompenda	3 11	Tübingen	68 4
Loxa	5 24	Atlantic Sea 38° 52' n. 3° 40' 0"	68 11
Cuenca	8 43	Ferrol	68 32
Quito	13 22	Paris	69 12
St. Antonio	14 25	Göttingen	69 29
St. Carlos	20 47	Berlin	69 53
Popayan	20 53	Carolath	68 21
Santa Fe de Bogata	24 16	Berlin	68 50
Javita	24 19	Danzig	69 44
Esmeralda	25 58	London	69 57
Carichana	30 24	Ystad	70 13
St. Thomas	35 6	Schleswig	70 36
Cartagena	35 15	Copenhagen	70 36
Cumana	39 47	Odense	70 50
Mexico	42 10	Helsinki	70 52
Atlantic Sea		Kolding	70 53
B. 20° 46' n. L. 41° 26' w. F.	41 46	Soroe	70 57
— 11 0 — 44 32 —	41 57	Friedrichsburg	70 59
— 12 34 — 33 14 —	45 8	Aarhuus	71 13
— 14 20 — 28 3 —	52 55	Aalborg	71 27
— 20 8 — 8 34 —	56 42	Odensala	71 39
— 21 36 — 5 39 —	47 49	Friedrichshaven	71 48
— 25 15 — 0 36 —	60 18	Gothenburg	71 58
Portici	60 5	Althorp	72 14
Neapel	61 35	Korset	72 24
Rome	61 57	Quistrum	72 27
Vesuv. Crater	62 0	Skieberg	72 29
St. Cruz, Teneriffe	62 25	Elleoen	72 38
Valencia	63 38	Helgeroae	72 39
Florence	63 51	Soner	72 41
Atlantic Sea, 32° 16' n. 2°		Christiana	72 34
52' w.	64 21	Ryenberg	72 45
Barcellona	64 37	Bogstad	72 34
Marseille	65 10	Bogstadberg	73 13
Nimes	65 23	Nasoden	73 2
Mailand	65 40	Bärum	72 44
Montpelier	65 53	Bolkesjoe	73 15

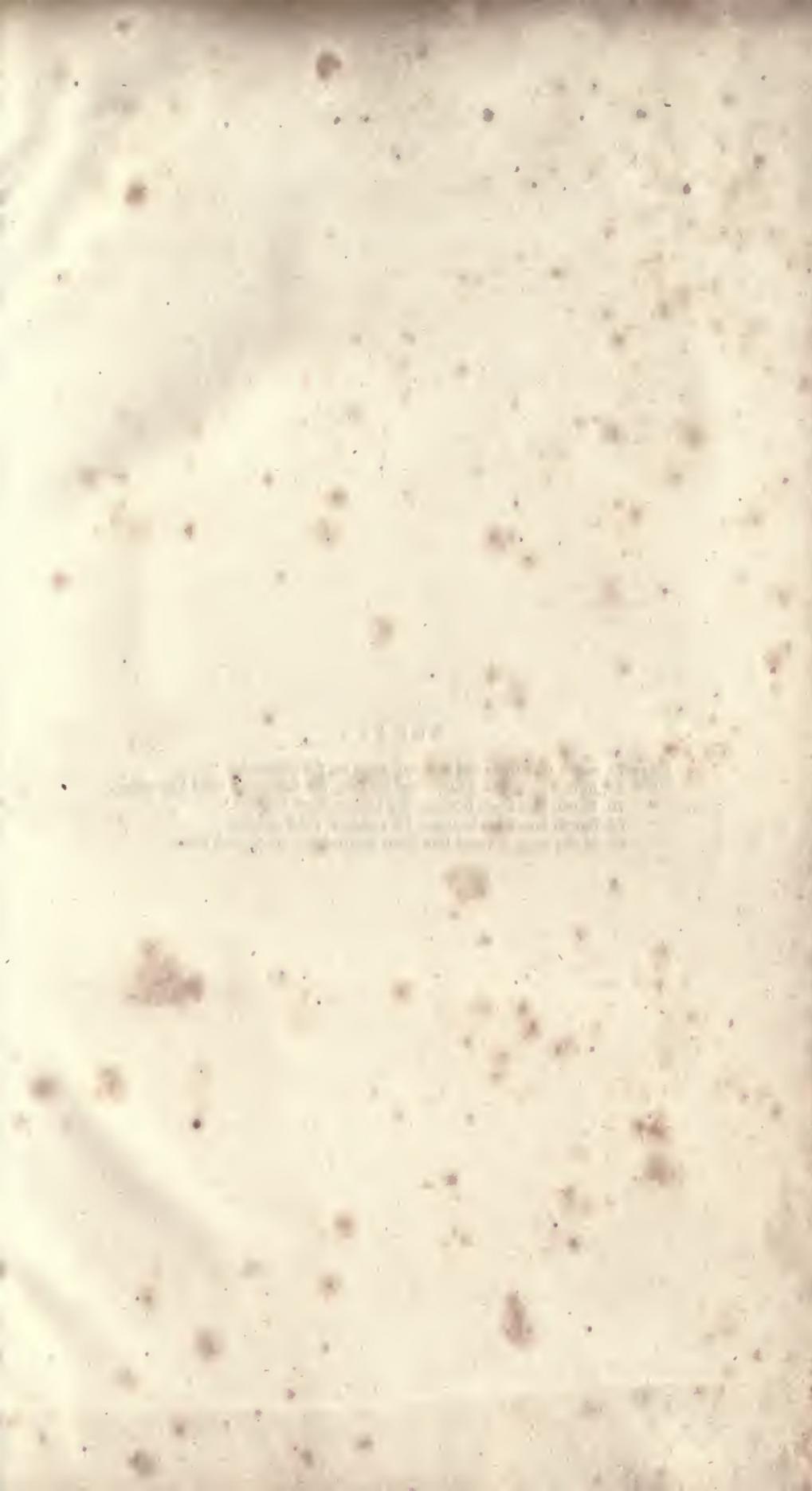
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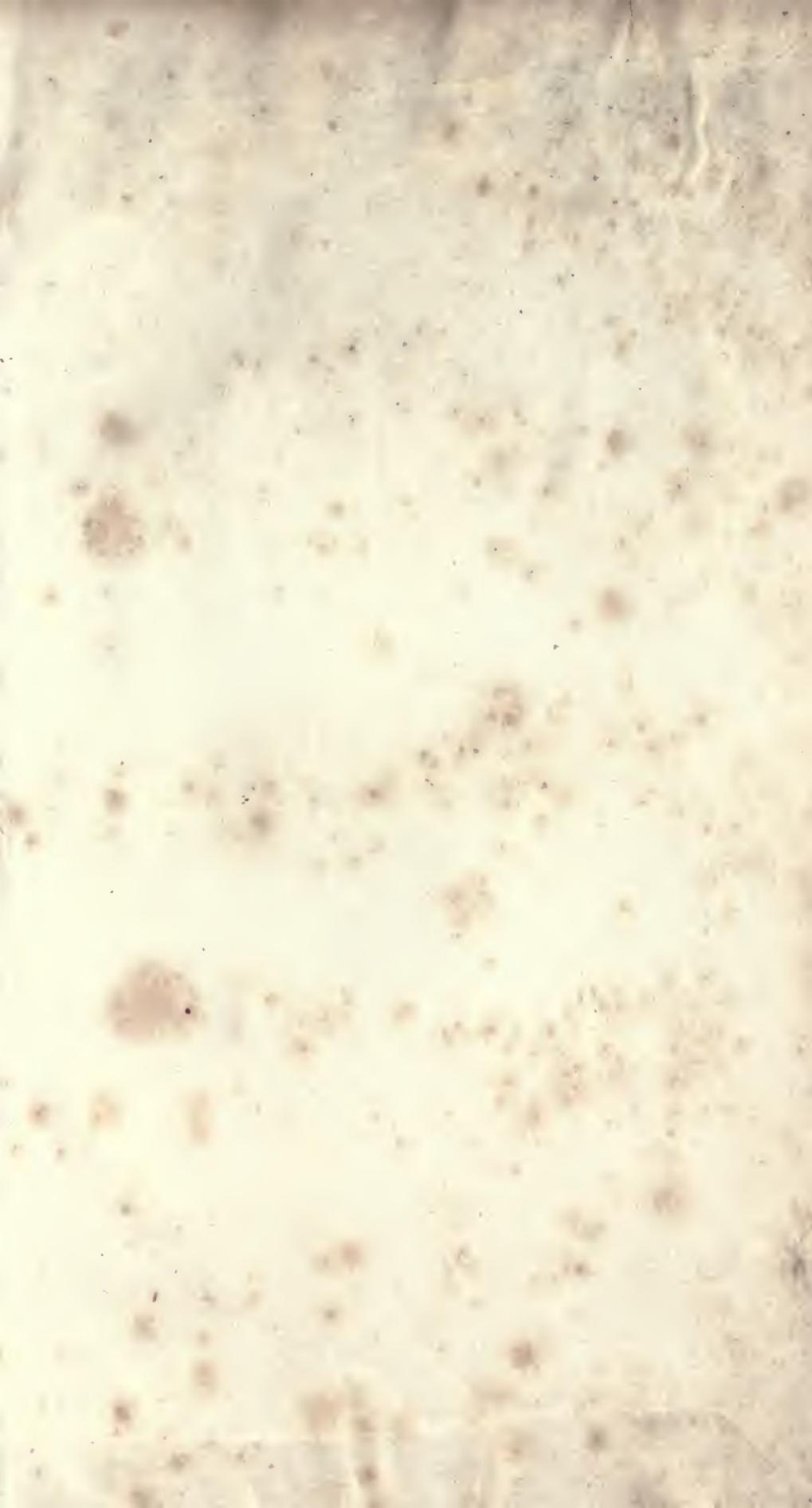
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E R R A T A.

- Page 43, ninth line from the bottom, read in, for beyond.
" 53, in the note, third line from bottom, for Lavoisier, read Lavoisier.
" 70, fourth line from bottom, for Danes, read Daines.
" 74, fourth line from bottom, for renders, read render.
" 89, in the note, second line from bottom, for was, read were.



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